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*The Kent Incorporated Society for Promoting Experiments in Horticulture*

IMPERIAL MYCOLOGICAL INSTITUTE
DEC 1947

# ANNUAL REPORT

(THIRTY-FOURTH YEAR)

1946

# EAST MALLING RESEARCH STATION

Near MAIDSTONE

KENT

*1st January, 1946 to 31st December, 1946*

*Price 10/- post free Great Britain only*

*Published October, 1947*

THE KENT INCORPORATED SOCIETY
FOR PROMOTING EXPERIMENTS IN
HORTICULTURE

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*Correspondence :* All correspondence should be addressed to the East Malling Research Station, near Maidstone, Kent.

*Telephone :* Aylesford 7294 (2 lines). *Telegrams :* Research, East Malling.

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# FOREWORD

THE hope that this Report for the year 1946 would be ready for publication by midsummer 1947 has not been realized, but at the time of writing it seems likely that it will be available to our Members more promptly than the last.

The progress that has been made in the reorganization of research programmes is reflected in the Sectional Reports in Section II, wherein will be found accounts of new lines of work that have been started since the end of the war and are now being actively pursued. Some of these show a return to the investigation of the more fundamental problems of the growth, cropping or health of fruitplants, while others are of more immediate practical concern to the fruitgrower. Perhaps it is as well to remind the impatient, however, that it may be some years before the inevitably slow processes of research will yield results that can be translated into firm recommendations to the fruitgrower. Meanwhile there are many of our Fellows and Members who like to follow closely the successive stages in our investigations ; they should find much to arouse their interest in the progress reports and reviews in Section III.

There are fewer bulletins for fruitgrowers than usual in the Report this year. Against this we would point to the several Bulletins on fruitgrowing subjects that have been issued recently by the Ministry of Agriculture and to others that are still in preparation. Many members of the research staff have contributed their quota to these Bulletins, while our Technical Section have devoted a great deal of time and thought to the collection and presentation of the information and have assisted in the editing of the Bulletins.

The Editors would like to express their thanks to Dr. E. E. Cheesman who has assisted them to pilot the Report through the later stages leading to publication.

T.N.H.

H.B.S.M.

*September 1947.*

# Section I

## *THE EXPERIMENTAL FARM*

By F. H. VILLIERS, with contributions from F. H. BEARD, D. H. HAMMOND and R. J. GARNER.

Although weather conditions in 1946 were entirely different from 1945, they can hardly be said to have been more favourable for fruit farming operations. Although there were few harmful frosts, last year's "summer" will long be remembered by all horticulturists, and it suffices to say that the succession of storms and gales, although causing considerable inconvenience, did not do as much damage on this Station as elsewhere in the country. Following a year of outstandingly good crops of almost all kinds of top fruit in 1945, yields in 1946 were, on the whole, light and the high winds during the late summer did not cause as much breakage of branches as they might have done had the trees been heavily laden. A few trees of some varieties of pears in an " on " year were blown completely out of the ground.

The season was about a fortnight later than in 1945, but conditions were by no means ideal for pollination ; the sky was frequently overcast and, although temperatures were about normal, bees did not appear very active. In addition to its bad effect on pollination, the continued lack of sun throughout the whole season seems to have had an adverse effect on fruit size, for individual fruits of almost all varieties of apples were considerably smaller than usual. Although it is impossible to say definitely that this was due to lack of sun, reports of under-sized fruits were so widespread that it is probable that this was so.

The later season continued throughout the whole summer. Strawberry picking did not begin until 14th June, and no apples were sufficiently mature to market before 31st July.

**Experimental Orchards.—Top Fruits.**

*Apples.*—The total crop from 49 acres of all varieties was 8,838 bushels (40 lb. to a bushel) or only just over one-third of last year's record crop. Owing to severe labour shortage in 1945, it was not found possible to do much fruit thinning so that many varieties overcropped and were consequently in an " off " year in 1946. In particular, Bramley's Seedling, which were not thinned at all in 1945 and yielded 5,900 bushels off 9 acres in that year, had only a sprinkling of blossom in 1946 and a total crop of only 539 bushels from the same area. The same was true in varying degrees of several other varieties, including Lane's Prince Albert which only yielded just over 1 bushel per tree. It did not, however, account for yet another poor crop of Cox's Orange Pippin in Kiln Field this year. There was plenty of blossom and no spray or other damage. However, as in 1945, there was only an indifferent fruit set and a very heavy drop of immature fruits in July. This Plot has now had nearly half of the trees removed and it is hoped that the extra room, combined with the addition of more pollinators and continued " renewal " pruning, will secure satisfactory crops.

Worcester Pearmain, which was thinned in 1945, was the only variety to give a really good crop, the total for all plots being 4,083 bushels, only 17 bushels less than the record crop last year. The rootstock trial of this variety has now kept up an average of nearly 4 bushels per tree annually, which on a 15 feet square plant works out at just over 700 bushels per acre, for a seven year period. On the other hand Miller's Seedling and Early Victoria, both notably biennial in habit, produced negligible crops in spite of severe thinning the previous year. Barnack Beauty, although it cropped at almost 1,000 bushels per acre in 1945, gave a small but useful crop of about 2 bushels per tree of excellent quality fruit.

The 20 acres of one-year-old trees planted on the Bradbourne Land in the autumn, 1945, became well established, due doubtless to the early planting and the moist conditions prevailing during the spring and summer of this year. There were no serious attacks by pests or diseases, though some trouble was experienced from the depredations of weevils which migrated to the apple trees when the interplanted peas were harvested. One dusting of 5 per cent. DDT dust, however, was sufficient to deal with these and the damage was very slight.

*Pears.*—The 7 acres of mixed varieties (1,700 trees) yielded only some 859 bushels (48 lb. to a bushel), most varieties being in an " off " year after the heavy crops of 1945. This, however, does not apply to the half-standard Dr. Jules Guyot on clonal pear rootstocks ; for, although they bore

some fruit in 1946, these trees have now cropped poorly for three years running. B. Clairgeau (just over 2 bushels per tree) was the only variety to give a worth while crop. Durondeau, Pitmaston Duchess and Souvenir de Congrès also yielded approximately ½ bushel per tree, but other varieties produced little blossom and scarcely any fruit. This is only the second complete " off " season that Conference has had in the quince rootstock trials since the variety first cropped in 1929. It is interesting that the sequence of events leading up to these two " off " seasons was very similar :—

1935 Frost—32 lb. seedless fruit per tree.
1936 " On " Year—81 lb. per tree.
1937 " Off " Year (little blossom)—4 lb. per tree.

1944 Frost—96 lb. seedless fruit per tree.
1945 " On " Year—120 lb. per tree.
1946 " Off " Year (little blossom)—3 lb. per tree.

*Plums.*—The acreage under plums was again reduced by the grubbing of 3½ acres of Victoria, Rivers' Early and a few other varieties on Plot 21, in the late autumn of 1945. The only plums now remaining on the Station, apart from windbreaks and one small variety collection, are the 6 acres in Deadman Field, consisting of 40 trees of Czar on different rootstocks, approximately 3 acres of mature Victorias in rootstock, stembuilding and spraying trials and approximately 3 acres of young gage plums in variety and rootstock trials ; with these last are planted Victoria, Warwickshire Drooper and Ontario. As mentioned in last year's Report, the older Victorias suffered considerably from breakage in 1945, owing to the weight of crop, and this helped further to reduce this year's crop of that variety ; this was only 1,033 halves (28 lb. to a half-sieve) or just under one quarter of the previous year's yield. Windbreaks and the younger plantings gave a further 541 halves, making a total crop of 1,574 halves of all varieties.

Some of the gage plum varieties cracked very badly, whereas others stood up to the wet weather very well ; it is, however, too early to say anything more yet. Nevertheless this factor is very important in the selection of gage varieties for commerce and is worth the careful attention of growers who intend planting dessert plums.

*Cherries.*—The crop of sweet cherries was by far the heaviest yet recorded, 1,494 halves (24 lb. to a half-sieve) from the 12 acres of all ages up to 25 years in the variety collection and rootstock trials. This was nearly 25 per cent. more than the previous highest crop (1,200 halves), produced in 1943. The bulk of the fruit came from the rootstock trials, all three varieties, Early Rivers, Turkey Heart and Bigarreau de Schrecken yielding well for their age ; there was some cracking due to the wet weather, but on the whole the quality of the fruit was good. The crop of acid cherries was not large ; those Morellos which were not dehorned in 1942 had been drastically dehorned and had many old branches removed in the spring in an effort to promote the growth of young bearing wood. It is not surprising therefore that the crop was small, 166 halves from 209 trees. The yield of Kentish Red was disappointing, only 116 halves from 120 trees, probably largely because of the lack of young bearing wood.

**Small Fruits.**

The 4 acres of mixed varieties of blackcurrants on Merryweather, though only planted in 1943, produced a useful crop of nearly 17 cwt. per acre of good quality fruit and made excellent wood growth. Strawberries, which are now confined to small scale trials, cropped well, though in this wet season mould and slugs were more than usually troublesome. The raspberry crop was disappointing, largely because of the attacks of cane blight, which killed more than half the fruiting canes of several varieties. Young cane was sprayed with DDT during the summer and it is hoped that this will prevent similar devastation next year by controlling the cane midge which is associated with the blight, though the technique is not yet fully worked out and further research is being done to ascertain the ideal times for these applications.

The loganberry crop was again rather disappointing this year, just over 2¼ tons from 1 acre. This was almost entirely due to damage to the lateral growths caused by late training.

**Arable Crops.**

The acreage under arable crops was only slightly reduced during 1946, for though twenty acres of the Bradbourne Land had been planted with one-year-old apples, it was decided, in view of the world food shortage, to intercrop these with peas for canning. The land made available by the grubbing of certain cherries, plums and stoolbeds, detailed in last year's Report, brought the effective arable acreage up to 164 acres, as compared with 167 acres in 1945. In addition to the peas already

mentioned, a further 9 acres of peas, 66 acres of corn, 30½ acres of potatoes, 38 acres of seeds hay and 7½ acres of roots and kale for cattle food were grown. As in the past, two yards of young Devon steers were kept to consume surplus straw and greenstuff and provide farmyard manure, a job which they did exceedingly well, producing some 600 tons of good dung at a gross cost of well under 15s. per ton. If the cost of meat and bone meal and similar fertilizers continues to increase and dung handling machinery to improve, home-produced farmyard manure seems likely to become one of the cheaper sources of this class of plant food.

*Potatoes.*—The whole 30½ acres was planted with Majestic this year, as this variety suits the land. The crop, 8 tons per acre, was rather disappointing, as pressure of work in the fruit plantations delayed the planting of the bulk of the acreage until well into May and blight destroyed the haulm quite early in the season. The whole area was, however, sprayed with 5 per cent. sulphuric acid prior to lifting with the object of preventing blight spores reaching the tubers and this seems to have been successful. All the tubers were of good quality except those on 3½ acres, grown as the first crop after the plums grubbed in the autumn of 1945. These were free from blight, but very scabby and almost unmarketable.

*Peas.*—The 13 acres of Alaska canning peas, grown between the tree rows of the two new plantations, seemed to appreciate the wet summer and did exceedingly well. To the purists who deprecate the intercropping of young plantations with soft fruits or market garden crops, because their manurial requirements conflict with those of the young trees, peas would seem to be an ideal solution, for the first two years at least. No quick acting nitrogenous manures are required for peas on any but the poorest land and the crop does not interfere in any way with the routine spray programme for young trees. Cleaning operations necessary for the peas also benefit the apples and the organic matter left in the soil in the form of the pea roots helps to build up soil fertility. The 13 acres of cropped ground yielded just over 22 tons of shelled peas and gave a net profit of some £289; this went a long way towards paying for fencing the new plantations and staking the young trees. Admittedly 1946 was a good year for peas, but against this must be set the fact that a commercial man would probably plant much nearer to his young trees, and so crop much more of his land than was thought advisable here.

The 9 acres of Lincoln peas grown on the farm also did well and yielded 16½ tons of shelled peas or just over 36 cwt. per acre.

*Cereals.*—32½ acres of wheat were grown altogether, including 9½ acres of Alté sown in mid-April in response to the Government's appeal. The overall average yield was approximately 5½ qr. per acre all of which was harvested in good condition.

28 acres of Barley also did well and yielded just under 7 qr. per acre and, in spite of a lot of trouble with the weather at harvest time, almost all was sold at the full control price for malting. The 5 acres of S172 oats, however, were almost a total loss for, although they looked very promising at harvest time, it was found impossible to get them dry without repeated turnings which shook out most of the grain. Only 22 qr. of oats were threshed.

*Seeds Hay.*—A very good first cut of seeds hay was gathered in fair condition. No attempt was made to take a second cut, as it was thought better to concentrate the available labour on the corn harvest and the aftermath was therefore ploughed in and will doubtless benefit the potatoes in 1947.

**Routine Spray Programme.**

In common with all other farming operations, the control of pests and diseases was made more difficult than usual by the adverse weather conditions during the spring and summer. Fortunately winter spraying was not influenced so much as the later applications and all winter washing was completed in good time without difficulty. As in previous seasons all plums and most of the apples on the Station received a single D.N.C. petroleum wash and the remainder of the apples 5 per cent. tar oil followed by petroleum oil emulsion. No spray damage of any kind was observed. Some capsid escaped destruction and damaged fruit of some varieties.

Again, no pears were winter washed this year, as the Entomology Section advised that this was unnecessary. All sweet and acid cherries were sprayed with 5 per cent. tar oil and the sweet cherries twice with Bordeaux mixture against Bacterial Canker. Unfortunately the spring application of Bordeaux was delayed by the weather and had to be put on just after blossoming instead of pre-blossom as recommended. This caused many of the leaves on Early Rivers to assume an autumnal colouring very early in the season and to fall prematurely, but did not affect the cherry crop.

The wet cool conditions during the late spring and early summer, particularly just after petal-fall, made the control of Scab very difficult, five lime-sulphur sprays in all were used on many Plots, but even this did not give complete control. Bad timing of sprays was probably the chief reason for the poor results. Good spraying days were few and our machinery was inadequate to make full use of the limited opportunities ; some of the post-blossom applications in particular were late and the intervals between them too long. When this happens, the scab fungus becomes established and of course no amount of spraying afterwards will destroy it. An additional mobile spraying outfit has now been bought and it is hoped to do better next year.

The delay in applying the first post-blossom lime-sulphur and nicotine wash allowed some of the Sawfly larvae to hatch and penetrate the fruitlets before spraying was completed, so that the control obtained was inadequate. The wet, cool summer also prevented complete control of Codling. Egg-laying was extended over a period of six weeks, so that a single application of lead arsenate did not give complete control and a second application was not possible.

Pests and diseases of black currants, loganberries, raspberries and hops were successfully dealt with by carrying out the recommendations in the spray calendar, though the appearance of the raspberry cane midge on a field scale has necessitated the spraying of all the raspberry experiments against this pest, in addition to the routine applications made later for the control of raspberry beetle.

F.H.V.

**Experimental Nurseries.**

Continuing the policy outlined in last year's Report, the area under large scale experimental nurseries was again reduced during 1946. The 10 acres of new stoolbeds planted in 1942 and 1943 are now well established and only 3 acres of old stoolbeds remain. In spite of this reduction, a total of 768,400 stocks of all grades was harvested, which, though satisfactory, was somewhat less than was anticipated, for the new stoolbeds seem to be rather slow in reaching maximum production. Rooting was well up to the average, but more layers than usual were in the smaller grades, possibly due to lack of sun during the summer.

Apart from a very short spell in October, weather for harvesting during the winter 1946-7 was appalling, all work being held up completely for the best part of two months by frost and wet. However, by concentrating all available labour on the job, it was possible to get all the stocks off and the layers down and covered before the buds had broken much.

The weather seems to have suited the worked trees for there was an excellent bud take and no spring grafting of failures was necessary. Altogether over 9,000 maidens were lifted.

The area devoted to the production of raspberry canes was also reduced from 6 acres to 2½ acres in 1946, but not before a record crop of some 180,000 canes had been harvested. These canes were a fine lot ; unfortunately, however, some of the beds were slightly attacked by the cane midge, so each cane had to be washed separately before despatch to remove all soil from the roots and so prevent the spread of this pest.

The production of other soft fruit plants and bushes was also on a considerably reduced scale, just sufficient for experimental needs and to maintain a nucleus of disease free, true to name plants.

In contrast to the general reductions in the large scale nurseries, 1946 was a year of great activity in the smaller experimental nurseries, in which some 7,000 trees were raised, 5,000 rootstocks budded, and an acre of stoolbeds maintained. The size of these nurseries bears no relation to the work involved. The trees were composed of close on 200 batches of apples, 30 of pears, 20 of plums, and over 250 varieties of cherry. The buddings required over 400 labels to mark the separate lots. The acre of stoolbeds contained 145 different kinds of rootstock. Almost half of these form an arboretum and provide a source of material for training purposes ; the remainder are undergoing stringent nursery tests in the search for improved rootstocks for particular purposes. The cherry trees, most of which are to be planted during the winter 1946-7 by the Kent Farm Institute at Borden to form part of the National Fruit Trials collection of varieties, were raised by using the clonal mazzard F12/1 to form the trunk and base of the main branches and working each of the three or four branches with the scion variety. Thus some 5,000 grafts were made in the construction of 1,500 trees.

D.H.H. and R.J.G.

**Hops.**

The acreage under hops has been reduced to 9¼ acres by grubbing ½ acre of the Seedling OI47. Though at one time a heavy cropper of great vigour, this variety, in common with many others of the same parentage (first generation from New Mexican Hop), has failed to develop its cones fully in recent seasons. Only five varieties in the Seedling garden were grubbed to make way for new selections. The wet weather in April, May and June caused Downy Mildew spikes to be more numerous

than for many years. Lateral spikes were particularly plentiful during July. It is therefore satisfactory to record that the regular removal of spikes followed by pre- and post-burr Bordeaux sprayings enabled us, in spite of a very wet August (over 5 in. of rain), to keep the bulk of the crop free from disease. Owing to the impossibility, in a garden of some 200 varieties of all seasons and characters, growing together in small lots, of applying the Bordeaux spray at the optimum time for all, a few Seedlings were attacked on either burr or cones. In contrast to 1945, mould (powdery mildew) was little in evidence. Aphids made their usual appearance in June, but two washings in close succession cleared up the attack.

The gathering of the crop was more difficult than usual. There was much loss of time due to heavy rain, and the severe gale on the night of 20th September caused damage to the cones of those varieties still unpicked. Rows of late varieties in the Seedling garden, exposed after the earlier ones had been picked, were badly damaged. Considering the season, yields were satisfactory. The total crop of about $7\frac{1}{4}$ tons was the heaviest since 1939; this, however, was not due to generally high yields, but because some of the newer plantings, such as $\frac{1}{2}$ acre plots of Brewer's Gold and Bullion Hop, have now reached maturity.

Some 4,500 sets of the New Varieties were raised and distributed amongst 14 growers. The demand for many of the New Varieties continues to be far in excess of supply. Some sets of clonal Fuggle and Goldings, raised at the Research Station and a daughter nursery, have been distributed to growers for the establishment of propagation gardens. In addition, some 9,500 sets of Fuggle and the Wye Seedlings were raised for the use of the Pathology Section in their Verticillium Wilt investigations.

The table below gives the valuations placed on the principal growths. Once again a well-known firm of brewers bought certain pockets on a P.V. valuation. Comparisons are available for five of the New Varieties. Except for Fillpocket, the P.V. valuation is the higher. It is interesting to note that both the ordinary and P.V. valuation agree generally as to the relative merits of the growths. Northern Brewer had the very high valuation of £38 7s. per cwt. on a P.V. basis. There are interesting variations in the values set on our several clonal Goldings.

F.H.B.

HOP VALUATIONS, 1946 GROWTHS (PER CWT.).

| Variety. | Ordinary valuation. £ s. | Valuation on P.V. (10$\alpha$) basis. £ s. |
|---|---|---|
| Brewer's Favourite (OP21) | 22 5 | |
| Brewer's Gold (C9a) | 23 0 | 26 16 |
| Brewer's Stand-by (HH44) | 22 10 | 26 14 |
| Bullion Hop (Q43) | 23 3 | 25 17 |
| College Cluster (N15 bis) | 22 0 | |
| Early Promise (X35) | 21 15 | 24 17 |
| Fillpocket (Z62) | 20 15 | 17 16 |
| Malling Midseason (BB28) | 23 0 | |
| Northern Brewer (WFB135) | | 38 7 |
| Sunshine Hop (V94) | | 26 3 |
| Quality Hop (OO63) | 21 0 | |
| OH44 | 23 0 | |
| Mixed Growths (New Seedlings) | 21 5 and 22 10 | |
| Fuggle | 22 0 | |
| Bramling | 25 15 | |
| Early Bird | 26 0 | |
| Canterbury Golding | 26 5 | |
| Eastwell and Petham Goldings, Mathon | 25 15 | |
| Rodmersham Golding | 25 5 | |

# Section II

## *GENERAL REVIEW OF RESEARCH WORK*

## *WITH LISTS OF PAPERS PUBLISHED DURING THE YEAR*

# I. POMOLOGY

By R. G. HATTON and W. S. ROGERS

**A.—Tree Fruits.—Rootstocks.**

The long-term rootstock trials of apples, pears, plums and cherries have continued to provide interesting information. Two apple rootstock trials, planted at 15 ft. square 28 and 29 years previously, reached the stage when they required thinning out for the sake of the remaining trees. The opportunity was taken to get trunk and branch weights of the mature half-standard Bramley's Seedling and bush Lane's Prince Albert apple trees which were removed. The trunk and branches of the largest Bramley's weighed nearly three-quarters of a ton. The remaining trees of Lane's all still show extension growth. Those on the most dwarfing stocks have settled down to a more or less constant height and spread and are adequately spaced at 15 ft. square, however.

The selection of the apple rootstock Malling Crab C was described and the behaviour of four scion varieties upon it for some twenty-five years was summarized (E241).

The first ten years' results given by Cox's Orange Pippin and Worcester Pearmain on a range of Malling rootstocks, planted on five contrasting soil types, have been published (E246).

Considerable progress has been made in the morphological description, identification and classification of the collection of quince rootstocks for pears. Scion compatibility tests on each clone have been conducted in conjunction, in the hope of finding a quince more universally suited to all pears, thus avoiding double-working.

**New Rootstock Trials.**

Two preliminary small scale field trials of the " IX Crosses " (new apple rootstocks raised by crossing M. IX with other stocks of the Malling series) and rootstocks tested for immunity to Woolly Aphid have been maintained. Both these trials are yielding much information on the behaviour of these rootstocks deliberately raised and selected for particular requirements and will be valuable in supplementing observations made on the two younger full scale field trials described below.

The full scale field trials of 24 new apple rootstocks believed to embrace five distinct " vigour " groups, tested for immunity to Woolly Aphid, planted out in winter 1945-6, have become well established and made good growth.

A further full scale trial of the " IX Crosses " has been planted on Malling loam, in November-December, 1946. Some 18 rootstocks are being tested with Cox's Orange Pippin, Orleans Reinette, Ribston Pippin, Egremont Russet and Sunset as scion varieties, and the rootstocks have been planted in blocks according to their expected vigour following an anatomical examination of their roots. All the rootstocks selected for trial have shown a good performance in the nursery when stooled.

The rootstock trial of high quality dessert plums bore a moderate crop at six years old. Definite differences in size of tree and in precocity of bearing are appearing.

In a small trial of sweet cherries, in which acid and sweet cherry rootstocks are compared, the autumn gales, following heavy rain, blew the trees on acid rootstocks over to as much as 45°. Not one of the trees on the sweet cherry rootstock, a selected vegetatively propagated mazzard, was disturbed. If left unstaked, the same happens to apples on M. IX.

The two peach varieties on four rootstocks prepared for a trial of fan-trained peaches will be planted during the winter of 1946-7.

The 11-year-old rootstock trial of cordon apples has been continued, and preparations have been made to test some of the more dwarfing of the " IX Crosses " as stocks for cordons.

A progress report of a trial of Cox's Orange Pippin grown as dwarf pyramid trees has been published (E233).

**Rootstocks in Germany.**

A final report of the visit made to the nurseries and horticultural research stations of the British and American Zones of Occupation in Germany has been prepared. The Malling system of rootstock classification is used throughout Germany. M. IX is much used for a special form of Dwarf Pyramid culture, the " Spindelbusch ", in the Rhineland. M. IV and M. XI are commonly used for bush apple trees and to a lesser extent M.I and M. II. In Northern Germany, severe winter frosts from 1940 to 1943 killed out many of the stoolbeds of layered stocks and seedling rootstocks are being used.

**Histological Investigations.**

A series of sections of roots and stems of a range of plum rootstocks has been prepared. A preliminary study has been made in apple and plum of the variations which may occur in the percentage bark of lateral roots due to (1) severe pruning and (2) close planting. The effects of several different scion varieties on the percentage bark of lateral roots of Common Plum rootstock have been measured.

An investigation of the relation of the percentage bark of the tap-root of one-year seedlings to vegetative vigour has been started on the lines of previous work relating the structure of lateral roots with stem growth.

The structure of the roots of thirty-four new clonal apple rootstocks, with ten standard rootstocks as controls, has been studied in detail and the results are being prepared for publication.

A survey of Yellow Egg plums has been carried out in Worcestershire and botanical descriptions made of the vegetative growth and fruit of some variant forms. Seed was collected from twenty kinds and will be sown during the spring of 1947. The structure of the tap-root of the seedlings will be examined in relation to the vigour and precocity of the young plants. The structure of the stem will also be examined in relation to ease of vegetative propagation. This work is being carried out with the objects of (1) studying variation in a group of cultivated plums and (2) obtaining an easy-rooting Pershore rootstock of medium vigour.

Observations and measurements have been made on the percentage bark and wood structure of two families of apple seedlings raised by crossing M. VII with M. IX and M. IX with M. XII. The size of tree and habit of growth will also be related to the root structure.

A series of sections has been prepared to investigate the structure and origin of adventitious roots in tree fruits.

A monthly examination of the " fine " roots of M. II apple rootstock has been begun, noting especially the seasonal variation in starch and oil content and the development of mycorrhiza. A preliminary survey of the structure of " fine " roots has been made in apple, pear, quince, cherry, peach, apricot, fig, hop, raspberry, loganberry and strawberry. Mycorrhiza have been found in all these plants.

A study has been begun of the structure of the union in compatible and incompatible combinations of pear and plum.

A preliminary paper has been prepared, in collaboration with the A.R.C. Unit of Biochemistry at Cambridge, on the application of biological observations on wild and naturalized plants to the study of fruit tree rootstocks, with special reference to plums.

**Propagation.**

The recently extended stockbeds of the new apple rootstocks immune to Woolly Aphid are beginning to yield satisfactory crops of rooted shoots and will shortly be available for large-scale propagation. By that time the recently established trials of trees on these " immunes " should enable a further " weeding out " to be made.

The apple rootstock series, known as the " IX Crosses ", budded in 1945, have, with one or two notable exceptions, produced excellent maiden trees. (See above.)

The extensive collection of quinces, used as rootstocks for pears, budded in 1943 with Williams' Bon Chrétien to test their compatibility with this variety, are now ready for union-breakage tests. Some of these clonal rootstocks seem to adhere more strongly to the scion than do the quinces in use in this country.

A set of plum rootstocks, including the so-called " Michaelmas Prune ", found in use in Kent, and Ackermann's Plum (Marunke), used on a large scale in Germany, have been budded with varieties Cambridge Gage, Early Laxton, Marjorie's Seedling and Victoria for field trial.

One hundred and sixty plum scion varieties were budded on each of the two rootstocks, Brompton and Common Plum, during the year, scions being supplied by the Royal Horticultural Society. It is hoped that the resulting trees will form the basis of the national collection of plum varieties and also yield some valuable information on varietal compatibility. The cherry collection of some two hundred varieties, and possible variants, was grafted in the spring and, except where unsatisfactory imported

scion-wood was used, the growth has been good. These trees have been raised within two years of the rootstocks leaving the layer bed. First quality layers of the selected Mazzard Malling F12/1 were planted in nursery rows, 4 ft. apart, in December, 1944, and tipped at 3 ft. Three or four branches were produced in 1945 and, in the spring of 1946, each of these branches was whip-and-tongue grafted. By the autumn the trees had grown so vigorously that they had met across the rows. In addition to the cherry variety collection, Mr. M. B. Crane's new varieties Bigarreau Merton, Merton Favourite, Merton Heart and Merton Bounty have been raised as bush and standard trees on Malling 12/1 at the request of the National Fruit Trials Committee.

The search for satisfactory dwarfing cherry rootstocks is being continued. So far the acid cherry rootstocks (*Prunus cerasus*) and some other species have not proved reliably compatible with our sweet cherry varieties ; the use of root cuttings from certain mature trees on Mazzard (*P. avium*), exhibiting restricted growth, is being considered.

The comprehensive rootstock collection, in the form of layers and one-year lined-out material has proved useful for training in the identification of rootstocks. An illustrated bulletin has been issued to aid the practical man to recognize the principal apple and plum rootstocks in the field (Eg34).

The investigations into vegetative propagation by cuttings continue. (See also III.A.) The lake bed at Bradbourne has proved useful in this work. The adjustment of water-table by improvised methods has clearly indicated the valuable natural features of this situation which could be exploited to the full by installing a reservoir and a system of conduits. Reference to the effect of this lake-bed soil, compared with normal loam, on the growth of cuttings has been made in three published articles (Eg33, Eg35, F43).

Various other aspects of propagation by cuttings have been further investigated.

**Double-working.**

The field trials with Williams' Bon Chrétien pear have been maintained. Isolated losses of single-worked trees have occurred during the year but none of the double-worked trees has broken at the union.

Further symptoms of incompatibility of President plum with Myrobolan B rootstock, when the President is top-worked with Victoria, have appeared. Fourteen-year-old trees composed in this way are making little growth and some have already died. The root system of one of these trees, which was still growing, but showed localized leaf yellowing, has been excavated. Some dead roots were found. A study of the unions, using injection methods, has also been made in collaboration with the Biochemistry Section. The problem is being studied further in younger material.

An exploratory " triple-working " trial with cherries, to test the practicability of producing dwarf trees of sweet cherries by interposing portions of other species, is now under way. Some of the intermediates are already failing to keep pace with the thickening of the sweet cherry stem.

**Cover Cropping.**

Two papers, on the use of annual cover crops (E229) and on methods of avoiding damage to annual cover crops by winter washes (E230), have been published.

A further report on the trial of grass and clover swards under Worcester Pearmain trees is in preparation. It has been possible to define a system of management for such swards so as to give beneficial effects on the trees.

The trial of five different cover crops as short-term leys, reported last year (E218), has been continued. Having been under cultivation since 1942, when the cover crops were disced in, the plots were re-sown in 1946, thereby commencing the second cycle of operations with the same five treatments.

The preliminary trial of various annual and biennial cover crops, which was started in 1943 under dwarf apple trees, has been continued. Included in this trial for comparison with annuals and biennials are permanent grass, farmyard manure, and straw with added " artificials ".

Several other apple and cherry orchards are divided into large areas cultivated and grassed down. These comparisons are supplementary to the more elaborately planned trials and yield general information on the effect of grassing down.

**Inorganic Fertilizers.**

The long-term investigation involving Cox's Orange Pippin and Beauty of Bath on several different rootstocks continues to show interesting comparisons between the various inorganic manurial treatments. The Bramley's Seedlings, on which the residual effects of potash are being observed with and without continued applications of nitrogen, were in their " off " year, and showed very little scorching of the leaves.

**Soil Moisture.**

The soil moisture tensiometers have continued to yield valuable information on the moisture conditions at various depths under cover cropping and cultivation.

**Pruning.**

The results of a preliminary trial of Renewal versus Spur pruning methods, applied to vigorous 30-year-old trees of Cox's Orange Pippin, are described on p. 49 of this Report. The results of a winter-pruning trial of pears have also been published (Ep11).

Differential leader and lateral pruning treatments have been begun on the new apple and pear dwarf pyramid pruning trials in Bradbourne gardens. A progress report on a dwarf pyramid trial, including two pruning treatments, has been published as mentioned above (E233).

**Fruit Thinning.**

In a long-term apple thinning trial, begun in 1945 on 15-year-old trees of Duchess' Favourite on M. IX, trees are thinned annually by the leaf count method, retaining one fruit per 10, 20 or 30 leaves. The unthinned control trees, which cropped so heavily in 1945 with small poor quality fruits, yielded but a handful of very large fruits per tree in 1946. Thinned trees carried a useful crop again with good sized fruits.

**Frost Damage Investigations.**

Observations on air temperature over grass and cultivated plots in a cherry orchard were continued in the blossom period of 1946. The varying crops of the rootstock plots on five different Kent soil series have also given information on altitude and aspect effects in relation to the wind frosts of spring, 1946.

Intensive work on frost damage has been restarted. The following preliminary trials have been made using artificially frozen apple blossoms :—

(1) Methods of testing resistance of flowers to frost by :—
  (a) discoloration of tissue ;
  (b) discoloration of tissue exudates ;
  (c) conductivity of tissue exudates.
(2) The effect of pollination on frost resistance.
(3) The effect of low temperature on pollen tube growth.
(4) The effect of protective sprays *before* and *after* freezing. Three types of sprays were used :—
  (a) waxy emulsions ;
  (b) oily emulsions ;
  (c) methyl cellulose.
(5) The effect of sprays capable of inducing parthenocarpic development of fruit in some plants. Two substances were used :—
  (a) methyl $\beta$ napthoxy-acetic acid, and
  (b) 2,4-dichloro-phenoxy-acetic acid.
  Both were applied after freezing.

Interesting preliminary indications were obtained, but the results were rather variable. This is probably at least partly connected with imperfections in the freezing technique, which it is hoped to improve.

**Biennial Bearing.**

The development of the research programme on this important subject has included an intensive study of the growth habits of trees of the variety Miller's Seedling in " on " and " off " year condition, available side by side on the same plot. Detailed serial records have been made on spur behaviour, shoot extension, leaf development, blossoming and fruit development. Similar studies have also been started on cordon trees of four varieties commonly regarded as typically biennial (Blenheim Orange and Miller's Seedling) and relatively regular in fruiting habit (Ribston Pippin and Ellison's Orange). With a view to presenting a well-defined picture of the conditions which contribute to the biennial bearing habit, serial photographs illustrating the different phases of growth as well as detailed records have been obtained and some very marked contrasts observed.

Preliminary trials of possible remedial measures have also been started, including " bud rubbing " and blossom thinning on trees in their " on " year, and partial defoliation of trees in their " off " year. Partial defoliation has been carried out on the varieties Miller's Seedling and Early Victoria

at various times of year to find out its effect on fruit bud formation. Some very interesting and promising results are appearing. Partial defoliation by sprays is also being tried.

The effect of earliness of fruit picking in relation to subsequent cropping is being studied on cordon trees of the variety Cox's Orange Pippin.

Maiden trees of Cox's Orange Pippin, Laxton's Superb and Worcester Pearmain on two soil types, comprising part of the new plantations, have been set apart for further study of the biennial bearing problem. They are being grown as open centre, delayed open centre and regulated trees ; renewal and spur pruning methods will be practised upon the open centre and delayed open centre trees, and other treatments such as fruit or blossom thinning will be superimposed later.

Injection of sample branches of trees in their " on " and " off " year with various nutrients has been tested, in collaboration with the Biochemistry Section, in an attempt to elucidate the part played by various elements in fruit bud formation.

**Varieties and Classification.**

The cordon variety collections of apples and pears have been maintained and have provided some useful material for the biennial bearing studies mentioned above.

The heaviest crop so far borne by the trees in the cherry variety collection provided excellent material for checking descriptions made in previous years. Of a few recently obtained varieties fruiting for the first time, one or two appear closely similar to known varieties and may prove to be identical.

Records of crop have been continued on the fan-trained acid cherry varieties.

The whole of the cherry variety collection has been reworked, in order to provide trees of uniform age and on one clonal Mazzard rootstock (F12/1) (see under Propagation). The actual number of varieties reworked—not all distinct—is 185 sweet cherries, 14 " Dukes ", (sweet × acid) and 21 acid cherries. In the summer of 1946 buds of more than 30 additional varieties, all sweet cherries, were obtained from various sources ; the total number will thus be over 250, of which it is expected that more than 220 will prove to be distinct.

Arrangements have been made for sending two trees of each variety to the Kent Farm Institute, for planting at Grove End Farm—the Cherry Sub-station of the National Fruit Trials. A monograph on these sweet cherries is in course of preparation.

In the dessert plum variety trial Early Transparent Gage, Ontario and Victoria all produced about 20 lb. of fruit per tree at 6 years old, and Warwickshire Drooper about 40 lb.

As mentioned above, detailed morphological descriptions are being made of a large series of quince plants, primarily intended for rootstocks.

Descriptions have been made of the vegetative growth and fruits of the collection of apricot varieties. The specimen trees of rootstock varieties in the arboretum are making good growth.

A plantation of new selected seedling apple varieties with suitable commercial kinds as controls is being established. The varieties which are being planted during the present winter (1946-7) are No. 456, now named " Tydeman's Harvest ", a very early highly coloured dessert apple, with Beauty of Bath as control ; No. 431, " Tydeman's Early Worcester ", with Worcester Pearmain as control, and No. 454 " Tydeman's Late Cox ", with Laxton's Superb as control. Space is being left to add during the winter of 1947-8 No. 432, " Tydeman's Michaelmas Red " (often referred to as " Late Worcester "), No. 452, " Tydeman's Martinmas ", fruits similar in appearance but later than Michaelmas Red ; and No. 455 " Tydeman's October Pippin " (often referred to as " Early Cox "), similar to Cox in appearance and flavour of the fruit, but earlier in season. These varieties are also being planted out as cordons on M. IX.

**Plant Breeding.**

The results of the fruit breeding work carried out at the Station have been summarized (E234). Plans are under way for the resumption of the breeding programme that was interrupted by the war. In the meantime the evaluation and testing of seedlings raised during the pre-war period has been continued. Apples immune to Woolly Aphid, from which the series of immune rootstocks have been selected, are now fruiting as scion varieties on M. IX. Several appear worthy of further trial. Interest in the new dessert apples raised to provide a succession of varieties resembling Worcester Pearmain and Cox's Orange is still very keen among growers. Many scions of Tydeman's Early Worcester have been distributed both in this country and overseas. Of the other varieties, Tydeman's Late Cox is also being tried out experimentally on a number of farms in this country. A paper describing both these varieties has been published (E239). Pear seedlings, raised between 1934 and 1936 from crosses between some of the best cultivated varieties, fruited during the year and a number have been selected for further trial.

**B.—Small Fruits.—Classification, Nomenclature and Varieties.**

*Raspberries.*—Two more of the Malling raspberry seedlings, which have already been described and distributed, have now been given names.

" Malling E " (numbered 33/132) now becomes " *Malling Enterprise* " ;

" Malling L " (numbered 34/42) now becomes " *Malling Landmark* ".

In the trial comparing new seedlings with standard varieties, the crop of 1946 was again much reduced by cane blight. The outstanding result was the increase in crop produced by the DDT spray applied to part of the plot in 1945 ; the average crop of all varieties was almost exactly doubled (half the remainder of the plot was unsprayed, and half sprayed in 1945 with lime-sulphur). Each of the nine varieties gave an increase, which varied from 40 per cent. for Malling Landmark and 55 per cent. for Norfolk Giant, to more than 250 per cent. for Baumforth B. The varieties most susceptible to cane blight, Malling Enterprise, Malling J, and Malling K, did not give the largest increase—probably because, in spite of the DDT spray, they became heavily infested with midge in the latter part of the summer of 1945 (see V and VI. B).

On the part of the plot sprayed with DDT the remaining varieties carried a very satisfactory crop. For the fifth year in succession, Malling Landmark was again first ; with somewhat over 4½ tons per acre, it still maintains its lead of about 35 per cent. over the next heaviest. It is fairly certain that, had the cane blight been completely eliminated, the order of cropping would have been widely different. It is highly unlikely, however, that any other variety would have equalled or surpassed Malling Landmark. It is interesting to find that Baumforth B had its heaviest crop so far recorded—somewhat over 2 tons per acre.

An extension of the cropping trial, planted in November, 1945, has made satisfactory growth in its first year. It includes Malling Promise and eight other recently selected seedlings ; the control varieties are Norfolk Giant, Newburgh and Malling H. Canes are now available for planting a further extension to include four still more recently selected seedlings. A number of the new seedlings have been sent to Scotland for trial.

*Loganberries and other hybrid berries.*—The collection has been maintained.

*Strawberries.*—The strain and variety trials cropped well. The record yield of 7·5 tons of marketable fruit per acre was produced by Huxley M. 44 at 2 years old. Royal Sovereign M. 40 was also top of its class with 3·5 tons of fruit on another plot. Perle de Prague produced its first full crop at East Malling. It is an early virus-tolerant variety, and as such may prove quite useful for growing with Huxley. Its quality was quite good, but its total crop was much below that of Huxley. Tested clones of Perle de Prague and Madame Lefebvre, both carriers of Crinkle, have now reached the stage where cropping trials can be planted.

A report was prepared on the condition of strawberry stocks and other small fruits noted on a visit to the British and American Zones of Occupation in Germany. Several new varieties were collected for trial, but no features of outstanding importance were noted.

**Propagation.**

*Strawberries.*—The agreed policy of leaving the propagation of tested clones as far as possible to commercial runner raisers under the Special Stock Certificate scheme of the Ministry of Agriculture has been followed out, and only small nuclei have been maintained of those varieties which have already been distributed (Royal Sovereign M. 40, Huxley M. 44 and Oberschlesien M. 42). New and promising clones of other varieties tested for virus content by the Pathology Section (see V.), are now under pomological test and are being worked up for distribution as soon as the cropping tests justify this course. These include Madame Lefebvre, Perle de Prague, and Western Queen. Other varieties including Early Cambridge, Auchincruive No. 9 and Jucunda are one stage later in the tests.

*Raspberries.*—The production of the cane nurseries has been good.

**Breeding.**

*Raspberries.*—The latest families of seedlings now number more than 1,400 plants. Of these, somewhat over 300 yielded their first fruit in 1946 and showed very good promise. It is intended to propagate all the most hopeful seedlings, half the available canes of each to be planted at East Malling and half in Scotland.

*Black Currants.*—In the cropping trials with new varieties of black currants raised from crosses between the principal commercial varieties several show promise and one, which has exceptionally late maturing fruits, has been sent for trial to the National Fruit Trials.

*Strawberries.*—Two seedlings of promise in the trials with selfed seedlings of Royal Sovereign have been selected for further trial. Several families from crosses between Royal Sovereign, Sir Joseph Paxton, Huxley and Pillnitz have not yet fruited and a family of selfed seedlings from Huxley Giant will be planted out for fruiting during the coming season. Further work is planned.

**Cultural Measures.**

*Loganberries.*—Records have been maintained on the manurial and cover-cropping trial of loganberries.

*Black Currants.*—In the trial in which straw and other organic manures were applied before planting, the applications were repeated after an interval of 2 years.

Other trials involving annual applications of various manures and pruning have been continued.

*Strawberries.*—The cultural trial planted in 1944, comparing different methods of arrangement and spacing of the plants in a fruiting bed, produced its first crop in 1946, and showed that under favourable conditions the strawberry fruit crop per acre can be almost doubled by adopting the most suitable methods. This season Royal Sovereign M. 40 grown in matted beds gave about 6 tons of marketable fruit per acre and in matted rows 5½ tons per acre, while single spaced plants in comparable plots yielded just over 3 tons per acre. No difference appeared in size of fruit or percentage of rotten fruit. This very striking result obviously needs confirmation in other seasons before general recommendations are made, for under drier conditions root competition may become a limiting factor ; and a further trial including these and other cultural methods has been laid out.

As the strawberry tarsonemid mite seems to be increasing again, warm water treatment of all runners of mite-susceptible varieties before planting has been resumed. A trial has also been planted in which the effects of these treatments on pests other than mites and on diseases such as mildew can be observed on relatively large blocks of warm water-treated and nicotine-dipped plants.

**Irrigation.**

No irrigation trial was carried out in 1946, because of the adequate soil moisture conditions, as confirmed by the moisture meters. Possible residual effects of irrigation in 1945 were studied, however.

**Frost Damage.**

Some frost damage was recorded on the " virus-tolerant " stock trial. Here Tardive de Leopold suffered most, Oberschlesien was next and Huxley had hardly any flowers damaged. In the trial of strawing in relation to frost with the variety Royal Sovereign there was practically no frost damage in 1946.

**C.—Nuts.**

Most of the walnut trees only bore a light crop in 1946, and a high proportion of the nuts of many varieties had imperfect shells, probably due to the very wet summer. Large numbers of imperfect shells were also found after the poor weather conditions of 1936 and 1939. Exceptions in 1946 were the early ripening variety Patching, and one or two varieties with small nuts, which ripened properly and had normal shells. Two progress reports were published, describing the main features of the walnut varieties now fruiting at East Malling (E235 and E236).

**D.—Horticultural Meteorology.**

The routine meteorological records were maintained. Special records of temperature and moisture in relation to various experiments were continued.

In collaboration with Statistics Section, the relationship between the accumulated day degrees above 42° F. and the time of blossoming of Bramley's Seedling has been investigated.

PUBLICATIONS DURING THE YEAR.

**In Relation to Tree Fruits.**

**The Behaviour of Hardwood Cuttings of Two Plum Rootstocks on Four Soils.** R. J. GARNER. Rep. E. Malling Res. Sta. for 1945 (1946), 49-53. (Eg33.)

**The Recognition of Some Apple and Plum Rootstocks in the Nursery.** R. J. GARNER and E. C. THOMPSON. Rep. E. Malling Res. Sta. for 1945 (1946), 130. (Eg34.)

**Plant Myrobolan Cuttings Closer to Improve their Shape.** R. J. Garner and E. S. J. Hatcher. Rep. E. Malling Res. Sta. for 1945 (1946), 131-32. (Eg35.)

**Frost Injury to Apples.** I. Modlibowska. J. Pomol., 1946, **22**, 46-50. (E228.)

Three types of frost injury were recorded on apple fruitlets following the frost in May, 1944: (1) loosening of the skin (2) radial splitting of the cortex and (3) discoloration of ovules and placenta. Loosening of the skin began to heal in most cases after about 3 days. Radial splitting was the most severe frost injury and was usually fatal. Recovery from internal discoloration depended not only on its degree and extent but also on the nutritional condition of the injured fruitlets. This was shown by the failure to develop of discoloured king fruitlets in unthinned clusters but their ability to do so and to mature when all other fruitlets in a cluster were removed.

Secondary flowers were less injured by frost than the fruitlets from normal flowers, but in spite of this they rarely developed.

In general, the frost in May, 1944, did not greatly affect the ultimate crop of apples at Merton.

**Cover Crops for Fruit Plantations. II. Annual Cover Crops.** W. S. Rogers and Th. Raptopoulos. J. Pomol., 1946, **22**, 92-102. (E229.)

1. This paper gives: I, A review of English orchard conditions in relation to use of cover crops; II, Characteristics and yields of various annual cover crops at East Malling; and III, Detailed experimental results of three years' growth of six annual cover crops, on the soil and on the growth and the cropping of 30-year-old Barnack Beauty apple trees in replicated plots.

2. The relation of time of sowing and discing-in of various cover crops to orchard operations, soil temperature and moisture is discussed. Summer cover crops are more likely to compete with the trees than autumn and spring ones. Figures given include yields of tares (*Vicia sativa*), tares plus oats (*Avena sativa*), crimson clover (*Trifolium incarnatum*), yellow trefoil (*Medicago lupulina*), rape (*Brassica campestris* var. *napus*), nettles (*Urtica urens*), and chickweed (*Stellaria media*), as autumn or winter cover crops; tares, tares plus oats, mustard (*Sinapis alba*), rape, rye (*Secale cereale*) plus peas (*Pisum sativum*), and broad red clover (*Trifolium pratense*), as spring crops, and lupins (*Lupinus* spp.), mustard, rape, tares and fat hen (*Chenopodium album*), as summer cover crops. Sweet clover (*Melilotus alba*) and sainfoin (*Onobrychis sativa*) are also discussed. All produced good yields under fruit trees, under some conditions, but yields varied greatly from plot to plot and year to year.

3. The cover crops whose effects were tested on apple trees for three years were (i) oats plus tares (winter); (ii) the same (spring); (iii) rye plus peas; (iv) rape; (v) broad red clover; (vi) mustard; compared with clean cultivation. Highest yields of green matter were given by (i), followed by (v) and (ii). All caused increases in the percentage of organic matter in the 0-12 in. depth of soil, when compared with the clean cultivated plots, after three years. The increases caused by (i), (v) and (iv) were the largest and were significant.

4. All cover crops caused an increase in the fruit crop, amounting to an average of 12 per cent. This difference was significant. No significant differences in tree growth, either in checking or stimulation, were shown by the trees over any of the cover crops, even after correcting the growth figures by co-variance with the previous performance of individual trees.

5. For East Malling conditions winter oats plus winter tares seems the most reliable cover crop at present fully tested. Broad red clover in spring has also given good results. Crimson clover is good, if precautions are taken to avoid winter damage, and mustard as a spring crop seems worth further trial. Several other crops, including sainfoin and annual sweet clover, are promising.

Certain weeds, including fat hen (*Chenopodium album*) and annual nettle (*Urtica urens*) can provide useful yields as autumn cover crops.

6. There seems little doubt that the use of suitable cover crops can add substantial amounts of organic matter to the soil in fruit plantations, and that these crops are less likely to cause a check to tree growth than either short-term leys or permanent swards.

**Cover Crops for Fruit Plantations. III. Time of Sowing and Winter Washing in Relation to Spray Damage to Annual Cover Crops.** W. S. Rogers and Th. Raptopoulos. J. Pomol., 1946, **22**, 103-10. (E230.)

1. Autumn-sown cover crops may be seriously damaged by orchard winter washes. A test was therefore made of different possible times of sowing crimson clover (*Trifolium incarnatum*) and winter oats plus tares (*Avena sativa* and *Vicia sativa*), and of applying orchard winter washes, in relation to spray damage, growth and yield of the cover crops, in two seasons.

2. The crimson clover was sown in July, August, September and October, and the oats plus tares in August, September and October. The five sprays, applied separately to all sowings, were: miscible tar oil wash in December, January and February, dinitrocresol-petroleum oil wash and field mixed petroleum oil-soap wash in February or March.

3. Choice of the most favourable times of sowing and spraying largely, though not entirely, obviated spray damage, and gave good results with both cover crops.

Time of sowing greatly affected yield, even in the unsprayed plots. Late sowing generally gave unsatisfactory results.

The least favourable sowing and spraying times resulted in complete cover-crop failure.

4. The best months for sowing crimson clover were July and August ; and for winter oats plus tares, September. The least harm to the cover crops from winter washes was caused when these were applied as late as possible ; tar oil in February, or dinitrocresol in February or March. Dinitrocresol was less harmful than tar oil applied early, and about equal to tar oil applied late. Dinitrocresol damaged tares and crimson clover more than oats. Tar oil, on the other hand, had a more severe effect on oats than on tares.

Petroleum oil, applied independently, did practically no harm to the plants.

5. A preliminary test, made with rye (*Secale cereale*) in place of oats, showed that it was superior to oats in its resistance to tar oil damage.

6. A preliminary test with a 6 per cent. thiocyanate oil wash suggested that this is markedly less harmful to many cover crops than tar oil or dinitrocresol.

7. It is concluded that vigour of the plant at the time of spraying, and intensity and duration of cold conditions following the spray application, are the main factors, apart from specific characters of individual cover crops and winter washes, controlling the reaction of cover crops to the harmful effects of winter sprays.

**The Intensive Culture of Hardy Fruits. II. A Trial of Dwarf Pyramid Trees on Malling Rootstocks.** A. Beryl Beakbane and Leslie R. E. Martin. Rep. E. Malling Res. Sta. for 1945 (1946), 45-8. (E233.)

**A Progress Report on Breeding Work with the Tree Fruits.** H. M. Tydeman. Rep. E. Malling Res. Sta. for 1945 (1946), 63-6. (E234.)

**Variation of Non-Clonal Franquette and Mayette Walnuts.** Elizabeth M. Glenn. Rep. E. Malling Res. Sta. for 1945 (1946), 67-9. (E235.)

**Progress Report on the Walnut Variety Collection at East Malling.** Elizabeth M. Glenn and A. W. Witt. Rep. E. Malling Res. Sta. for 1945 (1946), 70-4. (E236.)

**Cracking of Apples.** A. P. Preston. Rep. E. Malling Res. Sta. for 1945 (1946), 75. (E237.)

**Two New Apple Varieties Bred at East Malling.** H. M. Tydeman. Rep. E. Malling Res. Sta. for 1945 (1946), 121-2. (E239.)

**The Rootstock Malling Crab C.** R. J. Garner. Rep. E. Malling Res. Sta. for 1945 (1946), 126-9. (E241.)

**Soil Cultivation : How Much and Why.** W. S. Rogers. Agriculture, 1946, **53**, 113-15. (E244.)

Controversial views on depth of cultivation and mulching are discussed. The relation of cultivation to breakdown of organic matter is vital ; therefore organic matter must be maintained by manuring or other means. Given this, the standard recommended is to make a good seedbed, control the weeds, and give just such an amount of cultivation as, together with the fertilizer dressings, will unlock sufficient nutrients for the crop that is being grown.

**East Malling Research Station—Then and Now.** R. G. Hatton. The Fruitgrower, 1944, **101**, 240-1. (E245.)

A brief account of the founding and development of East Malling Research Station—1912-46.

**The Dessert Apple Plantation of Tomorrow.** T. N. Hoblyn. Rep. E. Malling Res. Sta. for 1945 (1946), 115-20. (E238.)

**Growth and Cropping of Apple Trees on Malling Rootstocks on Five Soil Series.** W. S. Rogers. J. Pomol., 1946, **22**, 209-25. (E246.)

Trials of Cox's Orange Pippin and Worcester Pearmain apples on standardized rootstocks on five Kent soil series have given quantitative data showing that choice of soil and site, and of rootstock, variety and disease control measures in relation to soil are of fundamental importance ; and that, even with soils commonly used for fruitgrowing, success or failure may depend entirely on one or more of these factors, which are largely within the control of the grower.

The soils were : Plot A, Wye Series (Brickearth) ; Plot B, Rattle Series (Clay with flints) ; Plot C, Lamberhurst Series (Wadhurst Clay) ; Plot D, Curtisden Series (Tunbridge Wells Sand, a very compact soil) ; Plot E, Ladham Series (Brickearth of the High Weald).

Both Cox and Worcester were budded on the rootstocks Malling I, II, VII and IX, and Cox on M. XVI was also included.

The results up to the time the trees were 10 years old were as follows :

(i) *Soil.* Soil had a great effect on growth, cropping and incidence of disease. Growth conditions were best on Plot A. Plot E had the next best growth condition and Plot B the worst. Plots C and D were intermediate.

Contrasts in amount of fruit produced were very great, and did not follow the vigour effects exactly. Plot A had much the largest crop, but Plot B, which produced the smallest trees, came second, partly owing to its having escaped spring frost damage in some years. Plot E, which was two years younger than the others, came into heavy cropping at about the same age that Plot A did so, viz. 8 years. Plots C and D produced quite large trees, but they did not bear very heavy crops. This appeared to be due to disease and frost rather than to soil, but the incidence of Canker was clearly related to soil type. Plots A and E (well-drained Brickearths) were practically free from serious diseases or leaf scorches, but Plots B, C and D (clay and compact loams) were severely affected by Canker and Scab.

(ii) *Rootstock.* Rootstock effect was greatest on the most fertile soils. Rootstock M. IX gave a very consistent performance under both favourable and adverse conditions, producing fruitful dwarf trees which came into cropping earlier, and were markedly less affected by Canker, than trees on other rootstocks. The trees on M. IX were, however, soon surpassed in crop per tree by the bigger trees which also cropped heavily while still relatively young, owing to the light pruning method used.

M. VII produced trees, in general, smaller than those on M. I and M. II, but a little too big to fill ideally the gap between M. IX and M. I and II up to 10 years old.

On all the soils, M. I and II made good bush trees with little difference in size between the two stocks. Cox on M. II cropped better than on M. I, especially on the heavier soils, but there was nothing to choose between the two stocks for Worcester.

M. XVI, while giving large and fruitful trees on Plot A, was so severely attacked by Canker on Plots B, C and D as to suggest that it may be unsuitable for use on such clays and other compact soils.

(iii) *Variety.* The Cox trees were more vigorous than the Worcesters, except on Plot B. On Plot A the Cox trees bore a much greater crop than the Worcesters, but on the other Plots the Worcesters bore a little more fruit than the Cox trees. There was relatively little difference between the amount of Canker on the two varieties.

**A Winter Pruning Trial of Pears.** T. N. Hoblyn. Rep. E. Malling Res. Sta. for 1945 (1946), 54-62. (Ep11.)

(*See also* III. F43 ; IX. E240, E243.)

**In Relation to Small Fruits.**

**Malling Promise Raspberry.** N. H. Grubb. Rep. E. Malling Res. Sta. for 1945 (1946), 133. (Esf55.)

**Black and Red Currants for the Garden.** H. M. Tydeman. J. roy. hort. Soc., 1946, **71**, 305-7. (Esf56.)

This is a brief popular account of the principal black and red currant varieties written from the point of view of the amateur gardener who desires to grow a number of varieties ripening in succession. The best varieties for this purpose are recommended and briefly described.

**Horticultural Meteorology.**

**Weather Conditions during 1945.** H. M. Tydeman and A. P. Preston. Rep. E. Malling Res. Sta. for 1945 (1946), 76-8. (H47.)

**Miscellaneous.**

**The Experimental Farm.** Section I. Edited by T. N. Hoblyn, with contributions from F. H. Beard, D. H. Hammond, A. P. Preston and F. H. Villiers. Rep. E. Malling Res. Sta. for 1945 (1946), 11-15. (E250.)

**General Review of Research Work, with Lists of Papers published during the Year.** Section II. Rep. E. Malling Res. Sta. for 1945 (1946), 17-44. (E251.)

# II. STATISTICS AND RECORDS

By T. N. HOBLYN

**Records.**

The preparation of summaries of the field records on long-term experiments still remains a large part of the Section's work. It should be emphasized, however, that even though these routine summaries are kept up to date, the analysis of the results of any particular experiment over a period of years with a view to publication is often a long and complicated process. First the accumulated data must be carefully sifted in collaboration with the research worker concerned, so that the measurement or series of measurements that appears to show best the comparative results of the experiment may be selected. (Often, for example, where records of growth or crop show no differences, the relationship of the one to the other reveals the true result.) Only when this has been done can the significance of observed differences be tested by statistical analysis. The results of several such long-term experiments have been examined during the past year, including several cultural trials ; the more recent history of the rootstock trials has also been reviewed. The effects of winter pruning treatments on nine varieties of pears, over a fifteen-year period, have been analysed and the results published. (See I. Epii.)

**Variation Studies.**

In the course of the examination of accumulated records of both long- and short-term trials much has been learnt about the amount of variation in various fruit plants, incidence of diseases and pests, etc., and also the exact form of distribution of the various quantities studied. Sometimes special investigations in the nature of uniformity trials have been possible with the object of improving experimental design and indicating in advance the best measurements to obtain. Thus, during two seasons 1944 and 1945, a study has been made of the Preservative Value (P.V.—ten times the percentage α-resins) of the Fuggle variety of hop (B58, see also VIII. A) ; and the variation due to the personal factor in routine spraying for Apple Scab control examined (Q41, see also V.).

More often, however, such information has to be garnered in the course of experiments not specially designed for the purpose. During the past three years many valuable data have been obtained on the incidence of the fruit tree red spider (see also VI.) and the variation in this pest is now being studied.

Recently, attention has been more specially focussed on the form of distribution, since it is now realized that many quantities do not conform to the Normal Distribution and cannot usually be analysed unchanged. The use of a " transformation ", such as the logarithm, is sometimes practicable, but results obtained when data are treated in this way are often difficult of interpretation. Much remains to be learnt about the uses and limitations of " transformations ", and in the meantime, wherever possible, experiments are designed and records made with a view to avoiding their use.

**Recording Technique.**

The technique of recording is generally based on the above variation studies, but often special trials are needed to establish the best method to use.

Several projects referred to in recent reports, especially in relation to sampling, have now been completed, and the results are being applied in field trials. Thus a wide range of simplified methods for recording weights of apple crops can now be recommended ; these vary from some that are very approximate, but easily carried out, to others that are more laborious, but give errors that are negligible compared with the variation inherent in any trials. Again, for apples, methods are now available for the unbiassed estimation of mean fruit size and for comparisons of the amount of red colour (see p. 77 of this Report). The development of similar methods for pears and plums will be taken further as opportunity permits. The ability of observers to measure fruit characteristics by eye has been further tested.

The statistical properties and inter-relations of various measurements of vigour have been further studied and the whole fundamental problem of the basic meaning of the concept of vigour is now to be taken up again. Many years ago it was realized at East Malling that no single measurement could describe fully the vigour of a fruit tree. Since then much new information has accumulated, including the final weights and measurements of trees at the end of their experimental life. It is intended to examine these records in detail with a view to the critical assessment of the value of each particular measurement.

The choice of growth and size measurements on dwarf pyramid apple and pear trees under different summer and winter pruning treatments is a problem that has needed attention. Various practicable methods have been suggested and their usefulness will be tested when an older trial of such trees is grubbed.

**Experimental Design.**

A paper on the design of field experiments with Cocoa has been published (E247). During 1946 experimental treatments were started on several of the " blank " apple plantations planted the previous year. In the design of these experiments the extended use of the trees over a long period was borne in mind and the addition of further treatments later on allowed for. Similar provision was made in the design of a trial of new apples raised at the Institute.

A series of apple, pear and plum plantations was designed for the Fernhurst Experimental Station, Plant Protection Ltd., in which provision was made for future spraying or cultural trials over a long period of years.

The Section has collaborated in the design of a series of large dessert apple plantations on a Kentish farm to be planted during the winter 1946-7 for a study of the economics of fruitgrowing.

## Publications during the Year.

**The Design of Field Experiments with Cocoa.** T. N. Hoblyn. Rep. Cocoa Res. Conf. London, 1945, 164-8. (E247.)

The principles which should guide the cocoa research worker in the design of his experiments are outlined. Field experiments are roughly grouped in three classes, viz. (1) variety trials (including rootstocks), (2) nutritional trials, and (3) cultural trials (including methods of cultivation, pruning, spraying, shading, etc.). Statistical analysis of long-term experiments on perennial crops is usually much more complicated than on annual crops, consequently the closest possible co-operation between experimenter and trained statistician is essential if the maximum information is to be obtained from the data evolved.

**A Study of Variation in Preservative Value of Hops.** S. C. Pearce and F. H. Beard. J. Inst. Brew., 1946, **52**, 250-5. (B58.)

During the two seasons 1944 and 1945 a study has been made of the Preservative Value (P.V.—ten times the percentage of α-resins) of a single variety of hop—the Fuggle—grown at East Malling, in an attempt to find out how it may vary, what are the causes of that variation and how accurately it can be measured.

*Season.*—The largest difference found during the investigation was between the two seasons. Although the hops were picked at the same time of ripening, dried and analysed under similar conditions, the average P.V. for all the 96 hills, from which samples were taken individually was 60 units in 1944, as against 39 units in 1945. Exactly what seasonal condition contributed to this large difference between the two years, which was general for hops at East Malling, is not clear.

*Differences between strains of Fuggle.*—Two Fuggle " clones " (vegetatively raised families each from a single selected hill) were examined. These clones had already shown differences in cropping, boldness of cone and resistance to injury from late frosts. They also showed consistent differences in P.V. On the average for both seasons Clone A had a P.V. of 46·5, while Clone N had a P.V. of 52·5, a difference of 6 units. This is not a big difference, but these are only two of many possible Fuggle variants and other clones might well show larger differences.

*Differences due to position in the hop garden.*—Although they cannot entirely be attributed to soil conditions, there were also consistent differences of up to 9 units of P.V. associated with hops taken from different parts of the same small hop garden, less than an acre in extent. It seems likely therefore that, where larger environmental differences exist, the differences in P.V. within a single variety may be considerable.

*Differences between individual hills.*—Differences so far commented upon are between averages of a number of hills ; but it was also found that some of the individual hills gave outstandingly high P.V.s. in both seasons, while others gave low ones. Here is the record of two *adjacent* hills :—

| | 1944. | 1945. |
|---|---|---|
| Hill A .. | 52 | 40 |
| Hill B .. | 69 | 44 |

The difference was not so large in the generally poor year, but in both years it was considerable, and seems likely to be permanent. Whether there are new variants within these carefully selected Fuggle

strains, or whether the differences are due to some local soil or environmental condition, cannot be established without further trial, but there is little doubt that quite large differences exist between individual hills within a single hop garden.

*How accurately can P. V. be measured* ?—If a sample (a 3-lb. Kilner jar of dried hops) is taken from a single hill, the P.V. of the clone to which that hill belongs can be estimated with reasonable certainty to within 17 *per cent.* ; *i.e.*, if the estimated P.V. is 50, it is reasonably certain that the true P.V. of the clone is not less than 41·5 not more than 58·5. But if the garden contains a mixture of clones, as do probably most commercial Fuggle gardens, several samples would have to be taken to estimate the average for the garden with the same accuracy. If single samples are taken from bulked hops, *e.g.*, cut from the pocket, in order to compare two gardens or two varieties, it is only possible to assert that no difference should be accounted real if it is smaller than 14 *per-cent.* This gives some idea of the latitude which should be allowed if hops are valued on a P.V. basis. Greater accuracy could be obtained by taking more than one sample, but this might not be possible under commercial conditions.

(*See also* I. E238, Ep11 and V. Q41.)

# III. PLANT PHYSIOLOGY*

By M. C. VYVYAN

## A.—Vegetative Propagation. (See also I. A.)

### Cuttings.

Experiments seeking to elucidate the principles governing rooting processes were continued, with some emphasis on factors operating through their effect on the parent plant. Although final conclusions must await the results of several years' experiments, results to date support the view that low nutritional status is a parental character associated with high rooting response.

During the year valuable experience has been gained of the " concentrated dip " method of treating cuttings with growth substances. This technique, by which the base of the cutting is dipped momentarily in a concentrated solution of the growth substance in 50 per cent. alcohol, compares favourably with the " solution " method, by which the cutting is stood for 24 hours in a dilute aqueous solution. Suitable concentration ranges of the growth substance dip are being determined for certain fruit tree rootstock varieties.

A series of full-scale, statistically designed trials investigating spacing, as well as soil effects on rooting and growth of plants from hardwood cuttings, are referred to elsewhere (see I. A : Propagation).

A paper (F43) has been published on the effect of soil conditions in the cutting bed on the habit of growth of one-year-old Myrobolan B plants.

## B.—Shedding of Fruits, Blossoms and Leaves.

### (a) Preharvest drop of fruits.

*Routine sprays.*—Anti-drop sprays were applied as a routine measure to most of the plantations of Beauty of Bath and Worcester Pearmain on the Station in 1946.

*Field trials.*—Worcester Pearmain again responded well to an anti-drop spray in a trial in 1946. (See p. 83 of this Report.)

Some trees of the apple variety Barnack Beauty were sprayed with α-naphthalene-acetic acid during the first week of October, 1946, to provide material for an experiment, in collaboration with Dr. C. West of the Ditton Laboratory, on the effect of the spray on the storage behaviour of fruit. The fruits were picked from some trees immediately after spraying, from others after an interval of a week, from the remainder after a fortnight. Little drop occurred even from the unsprayed trees during the fortnight. From the storage point of view this lack of drop was an advantage as it meant that any differences in sprayed and unsprayed fruit would be due to direct effects of the spray and not to indirect effects arising from selective dropping.

No preharvest spray, applied at the normal time, was tried on Cox's Orange Pippin in 1946, but a very early spray of α-naphthalene-acetic acid was applied on 1st July—three months before the fruit was picked. This was found to be still effective six weeks after application and it significantly reduced drop during the last six weeks before the picking date. A spray of 2, 4-dichloro-phenoxy-acetic acid, applied on the same date, had no significant effect.

*Small-scale intensive trials.*—Recent work suggests that there may be other substances that would control fruit drop in varieties, or during periods, when α-naphthalene-acetic acid is ineffective. The substances worth trying first are those that resemble naphthalene-acetic acid or dichloro-phenoxy-acetic acid either in chemical structure or in their power to produce certain responses, such as epinasty, hypertrophy, or root production, in plants. Several such substances are now available, usually in very small quantities. As it would be impracticable to test all these by large-scale field trials, it is necessary to select those of greater promise by preliminary small-scale experiments that require little material and few trees. A technique for such tests was tried in 1946 with some success ; in it the experimental unit consisted of a single fruit stalk from which the fruit had been removed to hasten abscission. This work will be expanded next season.

The results obtained at East Malling from experiments with growth substance sprays for the control of this drop from 1940-45 inclusive have been described in a paper (F42) and, in a technical communication (F44), recent published work from all over the world on the subject has been reviewed.

* Members of Staff of the Research Institute of Plant Physiology, Imperial College of Science and Technology are working in collaboration with this Section.

**(b) June drop.**

Cox's Orange Pippin commonly suffers more severely from a late " June drop " in July than from a true " Pre-harvest drop " just before picking. In 1946 a considerable control of this drop was achieved by applying a 10 part per million spray of α-naphthalene-acetic acid on 1st July. (See p. 83 of this Report.) Recent work in the U.S.A. has shown that the substance 2,4-dichloro-phenoxy-acetic acid is very effective over a long period with some varieties though of no use with others. Sprays containing 10 parts per million of this substance were therefore applied on the same date—1st July—but proved almost completely ineffective with this variety. Sprays of both substances will be tried next season on other varieties if trees bearing suitable crops are available, and an earlier application—in mid-June—will be tried on Cox.

**(c) Spray-induced drop.**

Work on this has been postponed until next season.

**C.—The Abscission Process.**

The collection, preservation and fixing of material for an anatomical study of this process has been continued in 1946 ; buds and trusses of blossom or fruit were collected from bud-burst till the end of the June drop. Sectioning and microscopical examination of this material has been begun.

**D.—Hormone Relations.**

**(a) General survey of fruit trees.**

This survey has commenced with a study of the diffusable auxin from developing shoots of apple and plum, using rootstock varieties which are being studied from the viewpoint of vegetative propagation. The types of shoot examined were lateral shoots on two-year Myrobolan B plants from cuttings, and vigorous shoots from a Crab C apple stoolbed. It was found that, early in development, auxin diffuses from all regions of the shoot, with a general gradient decreasing towards the base, and local differences relative to the nodes. Subsequently, the amounts of auxin diffusing from the shoot decreased to very low values in a manner which paralleled the falling-off in growth rates. The auxin manifested basipetal polarity of movement both in the stem and petioles.

**(b) Avena coleoptile technique.**

For bio-assay of auxin by the Avena technique, the oats seedlings are grown at a standard temperature and air humidity in a specially controlled chamber. A second and larger coleoptile chamber has now been designed and built adjoining the original chamber ; its equipment and furnishings are nearing completion and coleoptile tests in it will soon be possible.

## Publications during the Year.

**Experiments with Growth Substance Sprays for Reduction of pre-harvest Drop of Fruit.** M. C. Vyvyan. J. Pomol., 1946, **22**, 11-37. (F42.)

1. Sprays containing α-naphthalene-acetic acid, at concentrations ranging from 2½ to 10 parts per million, have been tried on five varieties of apple and one of pear, in experiments spread over five seasons.

2. A large, significant gain in crop was obtained with Beauty of Bath, Miller's Seedling and Worcester Pearmain apples. Conference pear also responded well when picked late. Use of the sprays with these varieties is recommended. Some response was obtained with Cox's Orange Pippin and Bramley's Seedling, but further tests are required before routine spraying of these varieties can be recommended.

3. Where two concentrations, 2½ and 5 p.p.m., or 5 and 10 p.p.m., were compared they gave similar results but, to ensure the best chances of success, 10 p.p.m. is recommended, though 5 p.p.m. may be sufficient for summer varieties in hot weather.

4. It is important to time the application of the sprays so that its effective period covers the time when drop is likely to be most severe. Ten days to one month before the picking date seems usually to be about right.

5. It is suggested that dropping tendency during any period is best calculated by the use of the equation :

$$Q = 100(\log_e X_1 - \log_e X_2)/(t_2 - t_1)$$

where $X_1$ and $X_2$ are the residual numbers, or percentages, of fruits on the trees at times $t_1$ and $t_2$, $(t_2-t_1)$ is the time interval in days, and Q is the required index of dropping rate.

6. It is suggested, further, that the most convenient index of spray effect is that calculated from ae equation :

$$q = 100(Q_c - Q_s)/Q_c$$

here $Q_c$ and $Q_s$ are the dropping rates for control and sprayed trees and q is the required index f spray effect.

7. A conversion table for easy calculation of values of Q, from values of summed percentage rops, is given in the Appendix.

**ropagation of Fruit Tree Rootstocks by Stem Cuttings. IV. Effect of Soil Conditions on Habit of Growth in Myrobolan B.** M. C. VYVYAN and R. J. GARNER. Rep. E. Malling Res. Sta. for 1945 (1946), 79-82. (F43.)

**ruit Fall and its Control by Synthetic Growth Substances.** M. C. VYVYAN. Imp. Bur. of Hort. and Plant. Crops, Tech. Comm. No. 18. 1946. (F44.)

A review of recent published work on the subject. Part I outlines the course of development n the apple from the initiation of a blossom bud to the fall of the ripe fruit, and summarizes present nowledge about various losses that occur before and during blossoming and in the young fruits. actors favouring the pre-harvest drop of nearly mature fruit are discussed more fully ; the chief eem to be hot spells, warm climates, nitrogenous manure, and shade or overcrowding. Some varieties iffer more than others.

Part II summarizes the little that is known as yet about the abscission processes responsible r the shedding of leaves, blossoms and fruits. Part III is concerned mainly with experimental nethods.

Part IV reviews more fully recent published work on control of pre-harvest drop by growth ubstances. Good control has been achieved in many, but not all, apple varieties, in several varieties f pear, but in no stone fruits. Naphthalene derivatives have been the most effective substances, ndole derivatives seem of little use, 2,4-dichloro-phenoxy-acetic acid has recently given good results. he standard strength of 10 parts per million is usually recommended, but weaker sprays are sometimes ffective, especially in hot weather. The period of control is said to last only some 3 or 4 weeks, ence careful timing is needed to ensure that this covers the period of drop. Very early or late sprays re rarely of value. One application is usually sufficient if correctly timed. Application in the form f dusts has sometimes given good results, but sprays are usually more consistent. Improved control as sometimes been obtained by addition of spreaders, citric acid or summer oil to the sprays, but effect of these on keeping quality of fruit must be watched. It would save expense if the growth ubstance could be added to a routine insecticide or fungicide spray, but these must usually be applied t the wrong time and questions of the compatibility of the substances are involved. The sprays eem to have little direct effect on keeping quality of the fruit unless they are used stronger than the tandard strength. Size, colour and keeping quality of the fruit may be improved by preventing he fruit from dropping too soon, but it is dangerous to retain the fruit on the tree until it is over-ripe.

Part V is devoted to practical recommendations on the use of these sprays.

Part VI is a summary, in tabular form, of all available published results of experiments on the control of pre-harvest drop by growth substances.

(*See also* I. Eg35.)

# IV. BIOCHEMISTRY

By W. A. ROACH

There have been a number of changes in staff during the year, consequent on the post-war reorganization of the Section's research programme.

A paper (K57) was published describing the flame method of spectrochemical analysis evolved, and used as a routine method, in the Section.

Notes were also published on nickel and multiple trace element deficiencies in agricultural crops (K58), a dropping mercury electrode of improved sensitivity (K59), supporting electrolytes in polarographic analysis (K60) and use of synthetic resins in the estimation of trace elements (K62).

A special grant from the Agricultural Research Council has rendered it possible to make a beginning on the improvement of the existing analytical methods and the exploration of new ones.

Work done in various parts of the country, but notably in Essex in co-operation with the County Officers, revealed in fruit trees widespread deficiencies of potassium complicated by a trace element deficiency. The results of analyses of leaf samples taken in the course of this work led to the surprising conclusion that curative tree injection of the trace element seemed to lead to an increase in the potassium content, whether or not potassium was also injected. This conclusion must remain tentative until further work is done. The injection of the trace element only had this effect when injected into a tree that was deficient of it. These results and the appearance of the trees encouraged the hope that curative injection of potash plus trace element might save many trees that would otherwise die before potash became available in sufficient quantity for applications to the soil in the usual manner.

Other evidence has accumulated suggestive of some connection between potash deficiency and deficiencies of iron and manganese in fruit trees, and as a high proportion of mineral deficiencies in fruit appears to be of this complex character, further study of the interactions of these deficiencies will be made.

A paper was published (K55) summarizing the main conclusions drawn from four years' work on mineral deficiencies in agricultural and horticultural crops carried out as part of a co-operative effort financed by the Agricultural Research Council. This work was continued in 1946. The results obtained add further confirmation of the economic importance of each of the six trace element deficiencies (manganese, iron, zinc, boron, copper and nickel) first diagnosed in the Marshlands of South Kent in 1934 by plant injection. Most of these results were obtained on plants that showed no symptom specific of any mineral deficiency. For example, wheat showing no such symptoms yielded 48 bushels per acre where unsprayed, 54 where sprayed with boron, 74 bushels per acre where sprayed with manganese and 76 bushels per acre where sprayed with manganese and boron. In other cases spraying with more than one element was much more effective than spraying with a single element and therefore essential to obtain the optimum effect. The optimum concentration of any one element was again found to be dependent on the levels of the other elements. The evolution of the composition of a mixture of six elements that will give optimum increase in yield and improvement in quality is, therefore, a problem of considerable complexity necessitating a large number of trial plots.

In an experiment on potatoes the yield was 14 tons per acre where unsprayed. Where sprayed with zinc alone the yield was 16¾ tons per acre and with manganese alone 17 tons per acre ; but where sprayed with both the yield was increased to 19 tons per acre. Further, in a superimposed factorial experiment, spraying with nickel gave an increase of nearly 6 tons per acre, copper and boron each 5 tons per acre. The extent to which these yield increases are additive is an interesting, but as yet unsolved, problem. Such results raise the question as to whether the best possible crops are yet being obtained on even the richest soils.

## Physiological Effects of Trace Elements*

By B. D. BOLAS and G. B. PORTSMOUTH

The very interesting visual responses obtained by injecting solutions of trace elements into plants deficient in those elements has suggested a study of the physiological processes, assimilation, respiration, translocation and growth rate at different levels of the various trace elements. This study may provide not only a fuller understanding of the effects of these trace elements on the metabolism

* This work is being carried out by members of the staff of the Research Institute of Plant Physiology, Imperial College of Science and Technology, working in collaboration with the Biochemistry Section.

of the plant but, in some instances, a more sensitive diagnostic method useful where visual responses are not obtainable.

In a preliminary experiment, the injection of an aqueous solution of manganese sulphate into lateral leaflets of potatoes suffering from manganese deficiency resulted in an increased assimilation rate in comparison with corresponding leaflets on the other side of the leaf (K56).

A further more critical experiment has been designed, using the potato as an indicator plant and manganese deficient soil from the Bradbourne lake bed, to examine the manganese effect in more detail. It is intended to extend the investigation to other elements, other plants and combinations of more than one element.

## Publications during the Year.

**Mineral Deficiencies in Agricultural and Horticultural Crops.** W. A. Roach. Rep. E. Malling Res. Sta. for 1945 (1946), 83-8. (K55.)

**Physiological Effects of Trace Elements.** B. D. Bolas. Rep. E. Malling Res. Sta. for 1945 (1946), 89. (K56.)

**A Flame Method of Spectrochemical Analysis.** W. A. Roach. J. Soc. chem. Ind. London., 1946, **65**, 33-9. (K57.)

A flame method of spectrochemical analysis suitable for routine use is described and illustrated by detailed drawings. The material (e.g. 25 mg. leaf powder) is folded between filter paper, heated in ammonium chloride vapour and finally fed automatically into an oxy-acetylene blowpipe flame in front of a spectrograph. It is suitable both for comparative diagnostic work and for quantitative analysis.

**Nickel and Multiple Trace Element Deficiencies in Agricultural Crops.** W. A. Roach and C. Barclay Nature, 1946, **157**, 696. (K58.)

In the course of work promoted by the Agricultural Research Council, wheat and other crops on the Romney Marshes responded to diagnostic leaf injections of boron, copper, iron, manganese, nickel and zinc and spraying with each of these elements was followed by significant increases in crop in all the crops tested : wheat, potatoes and broad beans, and probably in cabbages.

**Supporting Electrolytes in Polarographic Analysis.** J. P. R. Riches. Nature, 1946, **157**, 479. (K60.)

**A Dropping Mercury Electrode of Improved Sensitivity.** J. P. R. Riches. Nature, 1946, **157**, 520. (K59.)

**Use of Synthetic Resins in the Estimation of Trace Elements.** J. P. R. Riches. Nature, 1946, **158**, 96. (K62.)

The above three papers describe attempts to make available the new polarographic micro-methods of analysis for the estimation of trace elements in plant materials. In the first one, the advantages of ammoniacal buffers as supporting electrolytes in quantitive work are discussed.

(a) The steps on the current-voltage curves are well defined and well separated.

(b) Sulphite may be used to remove the oxygen from the test solution.

(c) The diffusion current remains well defined with increasing concentrations of supporting electrolyte.

(d) The diffusion current remains well defined in the presence of considerable concentrations of non-reducible cations. Thus the potassium and the calcium in the plant digest need not be removed from the test solution.

The second paper describes a form of capillary electrode which allows the use of increased rates of flow of mercury, without increasing the drop time. Such an electrode shows the expected increase in sensitivity, but the large rise in condenser current precludes its use at the highest galvanometer sensitivities. In polarographic tests involving catalytic reactions at the drop surface, however, where currents are dependent on the maximal surface area of the drop, this type of electrode may prove useful.

In the third paper, methods are described for the chromatographic separation of cations from a mixed solution, using micro-columns of the synthetic resin, Amberlite IR100. Since the anions in the original digest pass through the column unadsorbed, it is possible to obtain the cations on elution in association with any desired anion. Thus, in a plant digest, the trace elements could be separated from phosphate ions and, after elution from the column, estimated polarographically in an ammoniacal supporting electrolyte.

It is pointed out that many more polarographic micro-methods will become available for trace element analysis, once individual ions in the digest can be isolated quantitively from interfering substances in successive eluate fractions.

**Simplifications of the Roach Method of Diagnostic Plant Injection.** WINIFRED O. ROBERTS. J. Pomol., 1946, **22**, 184-8. (K61.)

Two modifications of the Roach method of diagnostic injection for the detection of nutrient deficiencies in plants are described.

In the first, a short length of soft cotton thread impregnated with the test solution and afterwards dried, is drawn with a fine darning needle through a leaf petiole or other tissue. In the second, a pad of cotton wool moistened with the test solution is bound with a piece of waterproof surgical or insulating tape over the wound caused by removing a leaf at the base of its petiole.

The distribution of the reagent in the cases tested (apple, pear, quince and Hydrangea) and the consequent development of chlorophyll, was the same as that resulting from the Roach tube method of injection.

The modifications described involve the use of easily obtained materials ; manipulation is simple, and the trials are not adversely affected by wind, wet weather or capillary creeping of the solution over hairy surfaces.

# V. PLANT PATHOLOGY

By R. V. HARRIS

**Pear Bacterial Blossom Blight** (*Pseudomonas prunicola*).

An account of this disease in east and south-east England was published (C216). Outbreaks in Kent of Blossom Blight of pear, apparently due to *Ps. prunicola*, were investigated, and a possible source of infection found. The results obtained are treated with reserve in view of the abnormally wet season, and the work will be repeated.

**Bacterial Canker of Plum and Cherry** (*Pseudomonas mors-prunorum and Ps. prunicola*).

Severe outbreaks were observed during 1946 in orchards not sprayed with Bordeaux. The trees affected were Victoria and Early Laxton plum, and Napoleon, Bradbourne Black and Ohio Beauty among other sweet cherries. Two cases of apparent failure to obtain control of the disease on sweet cherries by the recommended spray programme were investigated and will be kept under further observation. The escape of live bacteria from leaf spot in Victoria plum was studied and the work is being extended to cover sweet and acid cherries.

Work on the physiological behaviour of the two pathogenic bacteria was directed principally to finding the factors that determine the rate of multiplication and enzyme production.

Spraying trials were continued pending the development of sufficient infection on the plots to warrant conclusions on the degree of control obtained. A summary of present knowledge on control measures in Britain was published (C220).

**Apple Scab** (*Venturia inaequalis*).

Preparations of phenyl mercury chloride were further tested on a field scale and its promise as a spray against this disease was maintained (see VII. B.).

The influence of the personal factor in routine spraying was investigated for a third and final year in collaboration with the Statistics Section (see II.) and an account given of the preliminary work (Q41). Work on the influence of spreaders on the field performance of standard protective fungicides, which has been in progress over a long period, was also published (Q40).

Methods of building up an outbreak of the disease in the field principally for the purposes of fungicide testing were studied, and the influence of manurial dressings on natural infection was further observed.

**Apple Canker** (*Nectria galligena*).

A field spraying trial against this disease has yielded results tardily because of the meagre incidence of Canker in spite of the provision of local inoculum. Other methods of starting an attack were successfully studied and the influence of manurial dressings investigated.

**Brown Rot** (*Monilia fructigena*).

*Apple.*—A field spraying trial was started to determine the relationship between the incidence of Brown Rot and attack by Apple Scab and by certain insect pests, notably Codling Moth.

*Cultivated Hazel Nut.*—A similar problem, also investigated, concerned the association of fungal rotting of the nuts with attack by insects, notably the Nut Weevil (see VI. A.). Control of the disease on both these hosts by the application of fungicides was further studied.

**Raspberry and Loganberry Cane Spot** (*Elsinoë veneta*).

*Loganberry.*—Further evidence from the trial designed to determine the best time for spray applications showed that the pre-blossom copper spray cannot be omitted if good control is to be obtained and that post-blossom applications are necessary to maintain control. The latter are best achieved by adding a colloidal copper preparation to each of the sprays for Raspberry Beetle control.

*Raspberry.*—See Scottish Raspberry Investigation (p. 47).

**Raspberry Cane Blight** (*Leptosphaeria coniothyrium*, etc.). (See also VI. B.)

Observations by the entomologists during the 1946 season on natural infestations of raspberry canes by Raspberry Cane Midge (*Thomasiniana theobaldi*) provided additional evidence of the importance of this pest as a common precursor of the fungus-pathogens of Cane Blight. Assistance was

given in the identification of the fungi found in the course of this survey of combined Cane Midge and Cane Blight lesions, and a predominance of fructifications of two fungi other than *L. coniothyrium* was noted. The 1945 inoculation experiments were completed and further tests were made as a result of which, to date, five fungi (including the two organisms mentioned above and *L. coniothyrium*) have been shown to be contributory causes of Cane Blight cankers. The study of the etiological relationships of these organisms and the Midge is continuing.

**Verticillium Wilt.** (See also Hop Diseases. VIII. B.)

*Strawberry.*—Observations on the incidence of wilt and the prevalence of the two causal organisms *V. albo-atrum* and *V. dahliae* were made in the Wisbech area and other strawberry growing districts. To determine whether the transmission of the disease in runners is of commercial significance, trial plots were laid down in three localities using runners from both infected and healthy parent beds.

*Other hosts.*—The incidence of Verticillium in raspberries and potatoes was studied in a number of commercial plantations. These hosts and also rhubarb, tomato, cucumber, egg-plant and a number of ornamentals were used in controlled soil inoculation studies.

**Virus Diseases of Fruit Plants.**

*Strawberry.*—Seventeen samples of new seedlings and commercial varieties were tested by grafting to *Fragaria vesca* and a number of selections made for propagation and pomological trial. (See also I. B. Propagation.)

The results of experiments on the causes of deterioration of stocks of Huxley strawberry were published (C217). Two preliminary publications concerned with different aspects of the work on the separation of strawberry viruses by means of the aphid vector are also summarized below (C218, C219). A fuller account of this investigation is given on p. 113 of this Report.

*Raspberry.* (See also A.R.C. Scottish Raspberry Investigation, p. 47.)

Of three new seedlings grafted in 1945 one was found to be virus-free and two to be infected. Seven samples of Lloyd George were tested and one plant which appeared to be virus-free was selected for propagation and further study. Work on the classification of viruses found in commercial raspberry stocks by studying the symptoms produced by them on Baumforth's Seedling B and on Norfolk Giant was continued in conjunction with the investigation in Scotland.

*Loganberry.*—Research on Loganberry Dwarf was continued. In the early season of 1944 this disease was identified on three plants on the experimental loganberry plantation devoted to the control of Cane Spot, and the plants were removed and destroyed. A further spread of the disease on this plantation was observed in the spring of 1946 and similarly treated. In the autumn, however, many more cases were recorded and the Plot is now useless for its present purpose. A similar outbreak of the disease was also found in the spring of 1946 on the plantation of clonal loganberry plants providing the source of propagating material for this Station, and later in the nursery bed of " rooted tips " derived from this plantation. Hitherto, although the closely related Phenomenal Berry has proved highly susceptible to infection by Dwarf, cases on true loganberry have been comparatively rare. This severe outbreak in 1946 is therefore of great interest and is being further studied.

## Publications during the Year.

**Pear Blossom Blight.** H. Wormald. J. Pomol., 1946, **22**, 41-5. (C216.)

A Blossom Blight of pears in east and south-east England is described. Three pathogenic organisms have been isolated from affected blossoms ; the one of most frequent occurrence is found to be indistinguishable from *Pseudomonas prunicola*, one of the organisms causing bacterial infection of plum and cherry trees. A brief historical survey of previous work on closely allied bacteria is given and control measures are suggested.

**Experiments on Virus Degeneration of Huxley Strawberry.** I. W. Prentice, Mary E. King and R. V. Harris. J. Pomol., 1946, **22**, 11-16. (C217.)

A virus degeneration disease of cultivated strawberry (var. Huxley) in England is described. Symptoms are reduction in size and vigour of infected plants and a less glossy, grey-green appearance of the leaves. Marginal chlorosis of the younger leaves occurs, particularly in the autumn. The disease is graft-transmissible and has also been induced by grafting Royal Sovereign plants infected with Yellow-edge and Crinkle to vigorous Huxley plants also infected with Yellow-edge and Crinkle. It is not induced by grafting virus-free Royal Sovereign plants to vigorous Huxleys. The relation, if any, of the causal virus to the virus or virus-complex which causes Yellow-edge is unknown. The roguing of Huxley runner-beds for degeneration symptoms is advised.

**Resolution and Synthesis of Virus Complexes causing Strawberry Yellow-edge.** I. W. PRENTICE. Nature, 1946, **158**, 24. (C218.)

By means of the aphis vector, two viruses were isolated from a strawberry plant infected with Yellow-edge. When subsequently recombined in one Royal Sovereign plant they produced Yellow-edge, which is thus shown to be caused by a virus complex.

**Resolution of Strawberry Virus Complexes by means of the Aphis Vector** *Capitophorus fragariae* Theob. I. W. PRENTICE and R. V. HARRIS. Ann. appl. Biol., 1946, **33**, 50-3. (C219.)

*Capitophorus fragariae* which fed for 24 hours on strawberry plants infected with Mild Crinkle, Severe Crinkle or Yellow-edge transmitted the same virus (the " mild crinkle virus ") from all three sources. The symptoms produced by the virus and its vector relationships are described.

**Bacterial Canker and Leaf Spot of Plum and Cherry. A Summary of Present Knowledge on Control Measures in Britain.** M. H. MOORE. Rep. E. Malling Res. Sta. for 1945 (1946), 134-7. (C220.)

**Nettlehead Disease of the Hop** (*Humulus lupulus*). W. G. KEYWORTH and D. L. G. DAVIES. J. Pomol., 1946, **22**, 134-9. (C221.)

Grafting experiments with hop plants (var. Fuggle) affected with Nettlehead showed the disease to be graft-transmissible. There was usually a time interval of 9 to 12 months between grafting and symptom expression. Symptoms were suppressed during periods of warm weather and when affected plants were grown in a warm glasshouse. Observations in commercial plantations showed that the disease spread along the rows when these were " close-planted " and that disease outbreaks often occurred at the edges of fields near hedgerows.

Control measures suggested are the roguing out of affected plants and the use of healthy stock for propagation.

**Improving the Field Performance of Standard Protective Fungicides. I. The Place of Spreaders in the Spray Programme for Apple Trees.** M. H. MOORE. J. Pomol., 1946, **22**, 76-91. (Q40.)

Spraying experiments on apple trees showed that a spreader was unnecessary with lime-sulphur and nicotine for Scab- and Sawfly-control, given accurate timing of applications and adequate volume and pressure of spray. A spreader reduced spray damage in one experiment, probably by reducing the deposit through increased drainage from the tree. Weak Bordeaux mixture (2-3-100) proved unsafe, and is not recommended for apples, especially dessert varieties ; the inclusion of a spreader increased spray damage. Colloidal sulphur was improved by a spreader, especially when applied at low pressure with nicotine for Sawfly, but soap should be avoided on account of possible spray damage.

Light application of sprays diminished Scab- and Sawfly-control, but caused less damage than heavy applications.

There was but little difference in the effectiveness of the various spreaders tested, though a few of them were undesirable as they caused spray damage.

**The Personal Factor in Routine Spraying. I. A Preliminary Trial on Apple Scab.** M. H. MOORE and S. C. PEARCE. J. Pomol., 1946, **22**, 62-8. (Q41.)

Specially thorough application of lime-sulphur for Apple Scab control, when compared with ordinary routine spraying :

(1) reduced the tree-to-tree variability of percentage infection of leaves among the lower branches, and possibly also that of the fruits. High variability can therefore justly be attributed in some circumstances to indifferent spraying.

(2) gave significantly better Scab control on leaves and fruits when infection was measured by *percentage*, but not by *mean area of infection per leaf or fruit.*

The routine spraying of different farm workers is compared, and some theoretical and practical bearings of the investigation are discussed.

# VI. ENTOMOLOGY

By A. M. MASSEE

## A.—Tree Fruits.

**Apple Blossom Weevil** (*Anthonomus pomorum*).

Field trials have confirmed the efficacy of a 5 per cent. DDT dust applied at bud burst and again a week later; a 5 per cent. benzene hexachloride dust proved inferior to DDT. Excellent control has also been obtained with DDT sprays at bud burst and by adding DDT to the winter petroleum spray. Small-scale field trials also indicate that the weevil can be controlled by incorporating DDT in the routine D.N.C. and tar oil spray. (See VII. B. Insecticide Trials.)

A grower's bulletin outlining the control of the pest (D189) and more detailed papers dealing with (a) the biology and (b) the control (D194, D195) have been published.

**Woolly Aphid Parasite.**

The parasitized woolly aphid material kept in cold storage in the winter of 1945-6 at a temperature of 39° F. overwintered successfully and a high proportion of adults emerged the following June. This project has been completed and a paper outlining the methods used has been published (D192).

**Fruit Tree Red Spider.**

The special investigations are being continued at the Field Laboratory, Great Braxted, Essex, and also at East Malling.

*Life-Cycle and Control.* Many aspects of the *life-cycle* of the Fruit Tree Red Spider are being studied in the field and laboratory, particularly under Essex conditions. A description of a new technique for rearing the mites for this purpose and for tests of insecticides will be found on p. 122 of this Report. Many *predaceous insects* have been observed, of which a beneficial capsid is of considerable importance. The *migration* of the mite has been found to have an important bearing on its control in the field, and much information about the movements of the mites during the summer months is being accumulated. The " mangle " or " leaf imprint " technique for recording the results of winter spraying has again proved adequate and has been modified for use in summer spraying trials.

Spraying trials have been carried out for the third year to determine the value of certain *winter* washes against the eggs of the mite and preliminary *summer* spraying trials have been started. (See VII. B.)

*Laboratory tests of insecticides on the eggs.* The new technique of rearing mites on young apple seedlings has again been modified, and will greatly simplify the testing of summer and winter eggs on living plant material. (See VII. A.)

**The Effect of DDT upon beneficial insects associated with fruit.**

Observations are being continued on the effect of DDT upon beneficial, predaceous and parasitic insects associated with fruit. The correct timing of DDT dusts and sprays in relation to its effect upon beneficial insects is also receiving special attention.

**Effect of DDT upon various fruit insects.**

Preliminary work has been started on the effect of DDT upon the caterpillars of the Winter Moth group, of the fruit Tortricids and of the brown and green leaf weevils.

**Apple Capsid Bug.**

Field spraying trials are in progress to compare early and late applications of certain ovicides against this pest. (See VII. B.)

**The Nut Weevil.**

A preliminary investigation has been started to determine the association of the nut weevil with premature nut drop in the commercial nut plat. The life-cycle is also being studied. Preliminary laboratory experiments in 1946 showed that DDT is effective against the adult Nut Weevil, and this information is being used as a basis for field trials. (See p. 121.)

## 8.—Small Fruits.

### Strawberry Insects.

Further observations have been made on the life history of Strawberry Rhynchites (*Rhynchites germanicus*) and excellent field control obtained with DDT dusts (see p. 151). Field experiments on the control of Strawberry Blossom Weevil (*Anthonomus rubi*) are in abeyance until suitably infested material is available locally.

The economic importance of all species of Strawberry Aphids found breeding on cultivated strawberries is being studied. Population counts of *Capitophorus fragariae* have continued from May to August on selected farms in Hampshire, Worcestershire and Isle of Ely. Similar counts were made throughout the year on Kentish farms and Plots at the Research Station. Field experiments on Strawberry Aphid control by Nicotine Vapour in 1946 were hampered by unfavourable weather and variable results obtained. Arrangements have been made to compare the efficiency of the East Malling experimental machine with that of the Campbell Nicotine Fumigator.

A fumigation chamber is being constructed for testing methyl bromide and other insecticidal gases for the control of the Tarsonemid Mite. The study of the Fauna of cultivated strawberries has been continued and further insects added to the list.

### Gooseberry and Currant Aphids.

The biology is being studied as time permits. Material is being accumulated for further more intensive work.

### Control of the Vine Weevil.

Various insecticides are being tested against the larva.

### Raspberry Cane Midge.

Detailed observations have contributed to the knowledge of all stages of the life-cycle, the occurrence of successive generations and the nature of damage caused to raspberry canes by larval feeding. The occurrence of some parasites and predators has been noted. Some preliminary observations have been made in collaboration with the Plant Pathology Section on the association of various parasitic fungi with the damage caused by the larvae.

Small-scale trials of control measures directed against the eggs, larvae and overwintering forms have been made, and a field-scale soil treatment trial has been started. (See I. B. and V. Raspberry Cane Blight.)

### Black Currant Leaf Curling Midge.

A black currant plot has been established, and experiments on the life-cycle and control of this pest are in hand.

### Systematic Study of Phytoptidae and Tetranychidae.

Attention is being given to these groups of acari when time permits.

### Publications during the Year.

**The Apple Blossom Weevil and its Control.** G. H. L. Dicker. Grower, 1946, **25**, 240-1; Fruit-grower, 1946, **101**, 269-70 and 306; Gdnrs. Chron., 1946, **119**, 118; Farmers Wkly., 1946, **24**, 35 and 37; Rep. E. Malling Res. Sta. for 1945 (1946), 140-1. (D189).

**Notes on some Interesting Insects observed in 1945.** A. M. Massee. Rep. E. Malling Res. Sta. for 1945 (1946), 90-5. (D191.)

**Overwintering of Woolly Aphid Parasite** (*Aphelinus mali* Hald.) **in Low Temperature Apple Stores.** A. M. Massee. Rep. E. Malling Res. Sta. for 1945 (1946), 142-3. (D192.)

**The Biology of the Apple Blossom Weevil,** *Anthonomus pomorum* L. G. H. L. Dicker. J. Pomol., 1946, **22**, 140-52. (D194.)

The life history of the Apple Blossom Weevil, *Anthonomus pomorum* L., is described with special reference to the periods when adults emerge from hibernation and eggs are laid. Under Kent and Essex conditions weevils leave hibernating quarters over a period of approximately 5 weeks, beginning in late February or early March. A close correlation exists between temperature and numbers returning to the apple trees, very little activity being noted unless the maximum daily temperature exceeds 50° F. Egg laying begins when the fruit bud reaches the bud-burst stage, and continues for

three weeks. Under controlled laboratory conditions 15 females laid an average of 43·6 eggs in 1943 ; the same number averaged 45·5 eggs in 1944. A few males and females live for two years ; oviposition also takes place during the second spring. Only four days need elapse after females have taken their first meal until egg laying begins.

The weevils go into hibernation about three weeks after emergence from the capped blossoms ; at first any available shelter is utilized, followed by further movement in search of more comfortable quarters, which continues on a reduced scale throughout the winter.

*Pimpla pomorum* Ratz., is the only parasite that has been bred during the period 1943-5, the rate of parasitism being low, between 0·2 and 0·6 per cent.

**The Control of the Apple Blossom Weevil,** *Anthonomus pomorum* L. G. H. L. Dicker, F. C. H. Gayner and M. D. Austin. J. Pomol., 1946, **22**, 162-74. (D195.)

Preliminary laboratory trials in which Apple Blossom Weevils and their food were dusted with 1 per cent. Lethane HE-60, 1 per cent. Lethane 384, 5 per cent. dinitro-*o*-*cyclo*hexylphenol, 1 per cent. rotenone (derived from both derris and lonchocarpus roots), 5 per cent. dinitro-*o*-cresol and 5 per cent. DDT (dichloro-diphenyl-trichloroethane), all with a china clay base, and 3 per cent. benzene hexachloride with a gypsum-slag base, indicated that only the last three possessed any marked toxic effect against this weevil.

Further laboratory trials, in which the weevils and the food were dusted separately, showed that at 5 per cent., with a china clay base, DDT gave an average kill of 90 per cent., whilst benzene hexachloride killed 50-60 per cent. The latter at 3 per cent. with a gypsum-slag base gave kills ranging from 93-97 per cent., but was too heavy for efficient orchard dusting. D.N.C. (dinitro-*o*-cresol) proved too phytotoxic for further tests.

In field trials during 1943-5 a 5 per cent. dust applied at 40-45 lb. per acre at bud burst and a week later gave excellent control ; 3 per cent. DDT was less effective with indications that control was proportional to the quantity of dust used. Benzene hexachloride at 3 per cent. proved inferior to DDT at the same strength.

Difficulties of layout for dusting trials of top fruits are discussed and a simplified method found successful in the present trials is described.

**Apple Blossom Weevil and its control by DDT.** G. H. L. Dicker. Ann. appl. Biol., 1946, **33**, 124-5. (D198.)

This paper is a detailed summary of the author's contribution to a symposium on the agricultural uses of DDT.

The biology of the weevil is summarized and control by dusts discussed. Two applications of a 5 per cent. DDT dust at bud burst and a week later were shown to be more effective than dusts containing DDT or benzene hexachloride at 3 per cent. concentration.

**The County Distribution of the British Hemiptera-Heteroptera. Suppl. I.** A. M. Massee. Ent. mon. Mag., 1946, **82**, 94-5. (D193.)

# VII. PLANT PROTECTIVE CHEMISTRY

By H. SHAW

## A.—Laboratory Investigations.

### Chemicals.

Work has continued on methods of analysis of pest control products, particularly on the estimation of the amine salts of dinitrophenols potentially of value for the control of Fruit Tree Red Spider.

The reactions *in vitro* of the dithiocarbamates and thiuram disulphides have been further studied. In particular the decomposition, both spontaneous and under the influence of chemical reagents, of the sodium salts of substituted dithiocarbamates has been investigated. The disubstituted compounds give rise to the corresponding thiuram disulphides on long standing in aqueous solution. The dialkyl derivatives are decomposed by carbon dioxide or dilute strong acids into carbon disulphide, the amine or its salt, and the inorganic sodium salt. The form of the *p*H titration curve using N/10 hydrochloric acid falls into one of three groups according to whether the dithiocarbamate is an alkyl, dialkyl, or alkyl aryl derivative. These three types also show pronounced differences in toxicity to fungus spores, and a possible relation between reactivity and toxicity is being sought.

The possibility of the formation of phosgene from DDT in combination with other pest or disease control materials has been examined. Only vigorous oxidation by sulphuric acid-dichromate produced phosgene from DDT, and neither mild nor vigorous oxidation produced it from the ethylene compound.

The estimation of DDT on foliage is under investigation with a view to the study of the deposition and retention of this insecticide when applied in different forms. The fate of DDT in spray deposits is also being investigated.

### Ovicides.

The range of test organisms is being extended and preliminary tests using the eggs (summer) of Fruit Tree Red Spider and of Codling Moth have been carried out. A stock of *Ephestia kühniella* is being built up to provide non-seasonal egg material.

D.N.C. and several derivatives were further tested against eggs of *Aphis pomi*. The free phenol was more than ten times as toxic as the methyl ether or benzoate, but the acetate was only slightly less toxic than the parent substance. A preparation containing the diethyl ester of *p*-nitrophenoxyphosphoric acid (Bayer E600) proved to be extremely toxic to the eggs. The corresponding thiophosphoric ester (Bayer E605) was highly toxic to Codling Moth eggs and appeared to act like nicotine in preventing the hatching of the fully-developed embryo.

Against the summer eggs of Red Spider, azobenzene and tetramethylthiuram disulphide were more effective than di*cyclo*hexylamine 2 : 4-dinitro*cyclo*hexylphenate and gave results meriting fuller investigation. Colloidal sulphur at 0·5 per cent. sulphur was ineffective.

Available statistical methods have not proved entirely adequate for the evaluation of toxicity data and alternative methods are being sought in collaboration with the Statistics Section.

### Contact Insecticides.

Adults of *Tribolium confusum* have been used to evaluate the residual toxicity of insecticides. *Aphis fabae* is being raised to test systemic insecticides.

### Fungicides.

Attention has been concentrated on the salts of substituted dithiocarbamates and certain broad relationships between toxicity and molecular constitution have emerged. Sodium methyldithiocarbamate was the most toxic substance tested, giving 100 per cent. kill at a concentration of 0·01 per cent. The monoalkyl derivatives are more toxic than the dialkyl derivatives which, in turn, are very much more toxic than the alkyl aryl compounds. In each of the three series toxicity decreases slowly with increasing length of the alkyl chain. The amine salts tested did not differ substantially in toxicity from the sodium salts.

Preliminary tests showed sodium benzyldithiocarbamate to be highly toxic, about ten times more so than the dibenzyl derivative.

Inversion of toxicity has been observed with many of the above compounds. It was most pronounced in the case of sodium dimethyldithiocarbamate and appears to become less marked as the series is ascended.

**B.—Field Investigations.**

**Insecticide Trials.**

*Raspberry Beetle.*—The comparison of DDT in different formulations was continued in 1946 and again all proved equally effective when applied twice to combat the larval stage. It appeared that a high proportion of adult beetles was killed within 48 hours of the first application, but the treated plots were rapidly recolonized, indicating a substantial loss of residual toxicity within three days.

*Apple Sawfly.*—Several substances were tested by application at two different stages :

(i) at petal-fall before hatching commenced, thus acting presumably as ovicides.

(ii) when hatching was at peak level and before penetration occurred, acting as contact insecticides.

DDT and two thiocyanates were ineffective as ovicides, but DDT and a thiocyanoethyl mixed ester were as effective as nicotine against the newly-hatched larvae.

*Codling Moth.* The preparations used against Raspberry Beetle were tested, together with a benzene hexachloride preparation, against Codling Moth. The trial failed because of a very low infestation, but interesting secondary effects in relation to Red Spider were observed. (See below.)

*Apple Capsid.* The experiment on the effect of time of application of a D.N.C.-petroleum wash was continued for a third year. (See VI. A.)

*Fruit Tree Red Spider.* The trials in Essex on the time of application and relative efficiency of petroleum and D.N.C.-petroleum washes, and the comparison of miscible oil and stock emulsion petroleum washes have been continued. A new trial on summer control has been started. (See VI. A.)

In a trial against Codling Moth (see above) the Red Spider attack on trees sprayed with DDT was very significantly heavier than on trees sprayed with benzene hexachloride or lead arsenate. These latter, in turn, were more heavily infested than unsprayed control trees. A cumulative effect over several years may have been involved.

*Apple Blossom Weevil.* DDT was incorporated in tar oil and D.N.C. washes to determine its effectiveness in these combinations. It was also included in several forms in a petroleum oil wash. (See VI. A.)

During the year three reviews have been published dealing with the application of the newer synthetic insecticides, especially DDT, in agriculture and horticulture. (D190, Q42, Q43.)

**Fungicide Trials.**

*Apple Scab.* In 1946, a year in which the incidence of Scab was mainly post-blossom, a field demonstration trial showed that phenyl mercury chloride at 0·005 per cent. in a sulphite lye dispersion or on china clay was as effective on Cox's Orange Pippin as a full-time lime-sulphur schedule, though control was indifferent. The china clay preparation was superior to the mercurial on lead arsenate, a result not in agreement with previous experience. In another trial where the chief interest was phytotoxicity, phenyl mercury chloride at 0·01 per cent. appeared to be safe in the china clay and lead arsenate preparations, but in sulphite lye caused damage. Here again the lead arsenate preparation proved fungicidally inferior to the mercurial on china clay or with sulphite lye or methyl cellulose. (See also V. Apple Scab.)

**Developments in Pest and Disease Control in Germany and Switzerland.**

During May and June, 1946, a visit was paid to Germany and Switzerland as part of a team investigating war-time developments in pest and disease control materials and methods. A number of industrial research organizations and state and provincial research stations were visited. Contacts were made or renewed with many research workers and valuable discussions took place. A full account has been prepared for publication as B.I.O.S. Final Report No. 1095.

## Publications during the Year.

**Some Uses of DDT in Agriculture.** H. Shaw. Nature, 1946, **157**, 285. (D190.)

This is a report of a symposium organized by the Association of Applied Biologists. It contains an account of papers on the use of DDT in smokes and for the control of Apple Blossom Weevil, of flies in farm buildings, of Sheep Blowfly, and of ticks on sheep.

**he New Insecticides DDT and Benzene Hexachloride and their significance in Agriculture.** H. SHAW. J. roy. agric. Soc., 1945, **106**, 204. (Q42.)

The history and development of the two new insecticides DDT and benzene hexachloride are viewed and their application to the control of pests infesting various agricultural and horticultural ops described. A comprehensive bibliography of the literature relating to these insecticides is ppended.

**eneral Considerations in the Use of DDT against Fruit Pests.** H. SHAW. Rep. E. Malling Res. Sta. for 1945 (1946), 138-9. (Q43.)

# VIII. HOPS

## A.—Varieties and Cultivation Trials.

By F. H. BEARD

### Commercial Varieties.

Very detailed records are being maintained on the two early and five late clonal Goldings. Data are being obtained on cropping, dates of coming into burr and hop, size and number of petals of cones, amount of seed, P.V., and incidence of Downy Mildew. Differences between the clones have been observed in all these records.

A report has been published on the hill to hill variation in P.V. of two Fuggle clones (see II., B58). Some 100 Fuggle hills from different sources are now becoming established. It is hoped to be able to select a few from these for a cropping trial.

### New Varieties.

The crops from some 140 new varieties raised by Professor Salmon at Wye were picked and dried separately so that the yields could be estimated and, where necessary, samples saved for P.V. estimation. Samples of fifty varieties were placed in airtight glass jars for subsequent analysis by Dr. A. H. Burgess at Wye. 82 new varieties were recorded in 1945 and have been reported on (B54). The incidence of mould (*Sphaerotheca humuli*) in 1945 (a bad mould year at East Malling) has been described (B57). The systematic testing of new seedlings for resistance to Verticillium Wilt continues. (See VIII. B.)

### Cultural Trials.

A trial of time of cutting the hills with and without subsequent pulling is the only trial in being at the moment. In 1946 " pulling " reduced the yield and March cutting was better than December or February cutting. Material for further trials is not yet fully established.

### Propagation Trials.

The softwood cutting trials initiated in 1945 (see B55) were continued in 1946. The results obtained appeared to confirm the findings of 1945. The harmful effect of a synthetic growth substance noted on Fuggle in 1945 has occurred with other varieties in 1946. Trials have been made to see if the differential varietal effects of a synthetic growth substance on ordinary " strap-cuts ", noted in an earlier experiment, were correlated with the date of planting or method of applying the growth substance.

The comparison of three distances of spacing cuttings in the nursery row has been repeated. Trials designed to measure varietal and seasonal differences in both the take and size of set produced in both the Goldings and the New Varieties have been continued. Varietal differences occur in both groups.

Accounts of the propagation experiments in 1946 will be found in Section III of this Report.

### Other Investigations.

Data have been obtained on the amount of pull required to detach the hop cones from the laterals and on the size of cones for all the principal varieties. The investigations need to be repeated to ascertain if there is much seasonal variation.

Measurements of firmness of attachment and size of cones when associated with the habit of growth will enable varieties to be classified according to ease of picking.

## B.—Hop Diseases.

By W. G. KEYWORTH

### Verticillium Wilt.

*Survey.*—During 1946 eight outbreaks were newly reported to the Research Station from Kent and Sussex. Of these, two were almost certainly of the progressive type, one small one being near to an old-established outbreak and the other, a large outbreak of at least two years' standing, being reported from a four-year-old garden in south Sussex. This area had previously been free from the progressive type of Wilt and it is thought that the disease had been introduced in planting material.

*Resistance trials* of the Wye Seedling varieties were continued. One variety was selected this year for further testing and plots of the older selections were grown in Wilt areas in commercial gardens. Resistance has been maintained in most cases, but certain of the varieties have shown a higher percentage of Wilt on some sites than on others. Crop records were made and the susceptibility of the varieties to other diseases noted.

*Studies of Verticillium strains.* The soil inoculation work was continued, using further isolates of *Verticillium albo-atrum* and *Verticillium dahliae* from a number of Wilt outbreaks and from other host plants. The virulence of these isolates was tested by using hops as indicator plants, and correlations were made with disease severity in the field. The isolates were also studied in artificial culture in an attempt, so far unsuccessful, to correlate their pathogenicity with morphological or physiological characteristics and thus classify them in the laboratory.

*Soil studies.*—Collaboration has been maintained with Wye College and Long Ashton Research Station in the study of the effect of soil conditions and plant nutrition on disease severity.

**Nettlehead.**

Observations on disease incidence in commercial gardens were continued. On one farm the use of aerial surveys gave information on the distribution of the disease in relation to the previous history of the fields.

**Split Leaf Blotch.**

A grafting experiment using about 200 graft units was started in collaboration with Long Ashton Research Station to determine whether this disorder is graft-transmissible.

## Publications during the Year.

**Twenty-ninth Report on the Trial of New Varieties of Hops.** E. S. Salmon. 1946. (B54.)

1. Of the 82 New Varieties tested, one (Bullion Hop) cropped at the rate of 27 cwt. to the acre, and five at from 20¾ to 22¼ cwt. to the acre.
2. The number of bushels (Imperial) of green hops required to the cwt. of dried hops varied from 74 to 129.
3. High analyses are recorded for a number of the New Varieties.
4. Information is given respecting the relative resistance to Downy Mildew shown by certain of the New Varieties in this country and abroad.
5. Particulars are given of the competition for the Challenge Cup offered by brewers for the best growth in 1945 of a New (Wye) Variety of Hop.
6. It is pointed out that fifty-two firms of brewers have undertaken to purchase annually some 6,000 cwt. of certain of the New Varieties. In 1945, 1,538 pockets, or approximately 2,300 cwt., of the New Varieties were distributed by the Hops Marketing Board. It is evident, therefore, that the existing acreage of the New Varieties requires to be considerably increased in order to meet the brewers' requirements. In this connection it is urged that an Experimental Station in the Weald should be established where the approved New Varieties could be tried out on Fuggle soil.

**Propagation Trials with Hops. II. Preliminary Trials in Propagation by Softwood Cuttings.** F. H. Beard and Dorothy J. Wilson. Rep. E. Malling Res. Sta. for 1945 (1946), 96-103. (B55.)

**Propagation Trials with Hops. III. A Comparison of the Performance of Cuttings made from Runners, Layers and " Straps ".** F. H. Beard. Rep. E. Malling Res. Sta. for 1945 (1946), 104-6. (B56.)

**Observations on the Incidence of Mould** (*Sphaerotheca humuli*) **on the New Seedling Hops at East Malling in 1945.** F. H. Beard. Rep. E. Malling Res. Sta. for 1945 (1946), 107-14. (B57.)

(*See also* II. B58 and V. C221.)

# IX. TECHNICAL SECTION

By H. B. S. MONTGOMERY

Once again we have to report a further great increase in the activities of this Section. The number of visitors totalled over 2,000, of whom almost 400 came as individuals, many without previous warning. In addition organized Open Days account for a further 800 visitors. It would, of course, have been impossible to deal with these numbers with the staff existing at the beginning of the year, but the timely return of two members of staff who were with the Forces just made it possible. Enquiries by 'phone and letter have also increased, advisory letters written by the Technical Section totalling over 2,000 apart from the more specialized enquiries dealt with by individual research workers. It is difficult to obtain any accurate count of 'phone enquiries, but those recorded show that at least 500 were answered by the Section.

The Section has produced three popular articles (see below) and has also given considerable assistance to members of staff, who in all wrote a further 13 growers' bulletins. In addition, collaboration with the Ministry of Agriculture in the production of their official fruit bulletins has continued and the bulletins on Plums and Cherries, and Strawberries are nearing completion. Two bulletins, " Apples and Pears " and " Fruit Tree Raising ", on which we expended much time and energy, were issued during the year.

Time could not be found to prepare more than one short broadcast talk to growers, but we have also assisted the B.B.C. in finding suitable speakers and in preparing scripts for their overseas services.

Our three fruitgrowing films have been in fairly constant use throughout the winter months and we have also helped the county officers and other teaching staffs with photographs, slides, lectures and material for preparing exhibits. We have collaborated with the Ministry of Agriculture in the preparation of film strips on fruitgrowing subjects. In conjunction with the Kent Education Committee the fruitgrowing classes for school teachers have been maintained and have been well attended.

## Publications during the Year.

**Dwarf Pyramid Culture.** Leslie R. E. Martin. Rep. E. Malling Res. Sta. for 1945 (1946), 123-5. (E240.)

**East Malling Research Station.** Leslie R. E. Martin. J. roy. hort. Soc., 1946, **71**, 359-62. (E242.)

An account is given of some aspects of the work carried on at East Malling Research Station of particular interest to amateur fruitgrowers, stressing the collaboration necessary between different departments before any work of real value can be completed. The fruit trees found in gardens a century ago are described and contrasted with trees grown in the planned garden of to-day. This necessitates a discussion on the reasons for using rootstocks, the methods employed in propagating trees and brief details of classic pruning experiments. Early work on soft fruit, leading to the Ministry of Agriculture's Certification Schemes, is also described.

**Fruit Tree Rootstocks.** Leslie R. E. Martin. Gardening Illustrated, 1946, **64**, 876. (E243.)

The make-up of a fruit tree is briefly described before more detailed information is given on the best types of rootstocks for use in private gardens. Special attention is drawn to the extra care needed to produce trees on M. IX rootstocks, and to the necessity of " double-working " certain varieties of pears on Quince C rootstock.

# A.R.C. SCOTTISH RASPBERRY INVESTIGATION

By R. V. HARRIS and C. H. CADMAN

This season has seen the culmination of the three years' initial programme of research on the incidence of disease on the Scottish raspberry crop, and in retrospect it may be fairly claimed that a comprehensive measure of the problems involved has been taken, and encouraging and substantial progress achieved, particularly towards a solution of the major problem of virus diseases.

At the instance of the Council, the scope of the work was enlarged during 1946 to include the interrelated entomological and pomological problems which had become aggressively apparent during the initial period, and this decision was implemented in April by appropriate additions to the research and assistant staff, and establishment of the Investigation, thus constituting a fully comprehensive raspberry research unit. These latter aspects of the investigation are being developed under the supervision of the Heads of the Entomology and Pomology Sections respectively, and it will be appreciated that the research programme on this side was largely unrealized at the end of 1946.

## A.—Plant Pathology. (See also V.)

### Virus Diseases.

*Analytical work.* The results of the 1945 experiments together with those from a series of confirmatory experiments made in the year under review have shown that both the common raspberry aphides, *Amphorophora rubi* and *Aphis idaei*, can act as vectors of certain raspberry viruses. Two different types of mosaic were transmitted from a presumed uniformly infected stock of Lloyd George to Norfolk Giant, St. Walfried and seedlings raised from a cross between these two varieties. Transmission was specific and the virus or viruses in each case were picked up by the vectors after one or two weeks feeding on the infector source. Successful results were obtained using 50 or fewer aphids per plant and the technique holds considerable promise as a means of resolving the virus complexes responsible for the degeneration of raspberries.

The results of the 1945 grafting programme have shown the acute need for this supplementary analytical technique. Relatively few of the virus symptoms dealt with appear to be of a simple nature ; these have been selected for further and more detailed study. The more severe types of disease responsible for degeneration are obviously due to complex virus associations, the precise nature of which must await analysis by means of the aphid vectors.

Examination of a fairly extensive range of samples from commercial stocks of Lloyd George served to emphasize still further the low virus-expressing capacity of this variety. Since the majority of the current commercially valuable varieties react similarly to the viruses, a resolution of the process of degeneration in such " tolerant " varieties appears, in fact, to be the crux of the virus disease problem. The development of a satisfactory scheme for the maintenance of healthy planting stocks of virus-tolerant varieties is the most pressing need of the industry at the present time pending the introduction of a comparable range of virus sensitive varieties.

Little fresh information has come to hand on the Leaf Curl disease of Norfolk Giant since the 1945 season. Neither of the species of aphides mentioned earlier in this Report has indicated transmission of the disease to date and the vector problem here is to be more intensively investigated in 1947.

Evidence from grafting experiments has again indicated that the virus or viruses responsible for Leaf Curl are non-expressed by Lloyd George, though the results are inconclusive owing to complication by other viruses present in this variety. Leaf Curl which has so far proved a singularly difficult disease to handle owing to its lethal effect on Norfolk Giant, has now been found to produce a non-lethal effect on the variety St. Walfried, and more detailed investigation is thus greatly facilitated. It is hoped to multiply up a uniformly infected stock of this variety for forthcoming testing work.

Data on the sensitivity of Leaf Curl to environmental conditions supplemented those of last year. Comparable batches of Leaf Curl infected canes grown in the open and in an unheated glasshouse at Dundee, and in the open at Rothamsted Experimental Station, showed a striking correlation between the severity of the symptom picture and thermal conditions. At temperatures of 65-70° F. partial or complete recovery of infected canes was noted, typical Leaf Curl symptoms reappearing when the temperature fell below this level.

*Stock testing work.*—The testing, for virus content, of samples of tolerant varieties for the purpose of raising nuclear stocks is rapidly becoming an important feature of the Investigation. To facilitate

**Preliminary Results.**

It must be emphasized that a period of two years is too short to allow any full judgement of the comparative merits of the two systems, but several interesting points have already appeared, some of which are of material importance in carrying out the methods. It therefore appears worth while to present the following data :—

**Spray damage.**

Following an application of 8% D.N.C.-petroleum spray in March, 1945, much damage to buds was observed, and the renewal-pruned trees were more severely damaged than the spur-pruned ones. Many buds, especially those towards the base of the long one-year-old shoots, left to " bud-up " in the renewal-pruned trees, fell out. This certainly lessened the number of buds available for cropping later, and indeed the bare spaces so left were still obvious two years later. Some damage to the fruit buds on spurs, on both treatments, was also noted, but the effect of this would be less obvious after the first year.

This observation was confirmed by a detailed record of spray damage taken the same year on a neighbouring Plot of mature trees of Cox's Orange Pippin and Worcester Pearmain, which included both renewal-pruned and spur-pruned trees. On this Plot also, axillary woodbuds on unpruned laterals were severely damaged in many cases ; and some fruit buds on spurs, after reaching the " burst " stage, died on renewal-pruned trees.

The damage was less striking on the spur-pruned trees. Young adventitious buds grew out from the base of spurs bearing damaged buds, so that within a week or two the damaged spurs on these trees were covered with leaves ; but the bare wood on renewal-pruned shoots persisted.

The distribution of the damage in this orchard strongly suggested that certain trees had received double spraying during sunny and drying weather, a form of damage described by Steer and Moore (1941).

These observations suggest that, when petroleum sprays are applied to renewal-pruned trees, special caution should be exercised to select favourable conditions and avoid double application or excessive drifting in a drying wind, under sunny conditions.

**Length of blossom period.**

Though it is well known that axillary fruit buds, formed on 1-year shoots, open later than fruit buds on spurs, it is not generally realized that, as this experiment has shown, fruit buds on 2- and 3-year wood also open later than those on spurs. It follows that the effective blossom season tends to be more spread out in renewal-pruned trees, which have many fruit buds on 1, 2 and 3-year wood, than in spur-pruned trees, where the great majority of the fruit buds are on spurs. This extended blossom period may be a very valuable asset in some seasons, especially if weather conditions are unfavourable for pollination in the first week of blossoming. It may also be helpful in escaping frost damage, for a smaller proportion of the flowers are in the most vulnerable stage at any given time.

An indication of the extension of blossoming was given by the 1946 blossom records. There was no appreciable difference in the mean date of first blossom on the renewal- and spur-pruned trees, but on 4th May, 14 days after the first blossoms opened, and when the spur blossoms were all over, the renewal-pruned trees had an average of 19·7 blossom trusses open on a sample branch of each tree, while the spur-pruned trees had only 2·5. This difference is statistically significant.

In 1947 closer records were made. Blossom trusses having three or more flowers open were counted each day during the blossom period, on spurs and 1, 2 and 3-year wood separately, on sample whole branches on the north and south sides of each tree. The records showed well-defined successive blossom periods for spurs, 3, 2 and 1-year wood, in that order, as illustrated in Fig. 3. In this diagram, the number of open trusses is expressed as a percentage of the total of the open truss counts for each wood type. Since a truss might be open on several successive days, this figure is, of course, to that extent smaller than the actual percentage of trusses open on any one day. The records from both renewal and established-spur trees are included together in this diagram. It is seen that even in this year, when the whole blossom period was short, the blossoms on 1-year and 2-year wood were both considerably later than those on spurs. The actual numbers of blossoms open on the various kinds of wood under the two pruning treatments on each date is shown in Fig. 4. In order to accommodate the very large number of spurs on these old trees, and the relatively small number of blossoms on 1-year wood conveniently in one diagram, the vertical scales have been adjusted as shown. The comparisons shown best are thus the relative numbers of blossoms given by the different pruning treatments within each wood type, and the periods of effectiveness of the blossom on the different kinds of wood. The diagram shows clearly that the renewal-pruned trees have less blossoms on spurs and many more on 3, 2 and 1-year wood that the established-spur trees, so securing a more even distribution of open blossoms over the whole blossom period. The contrast in number of blossoms

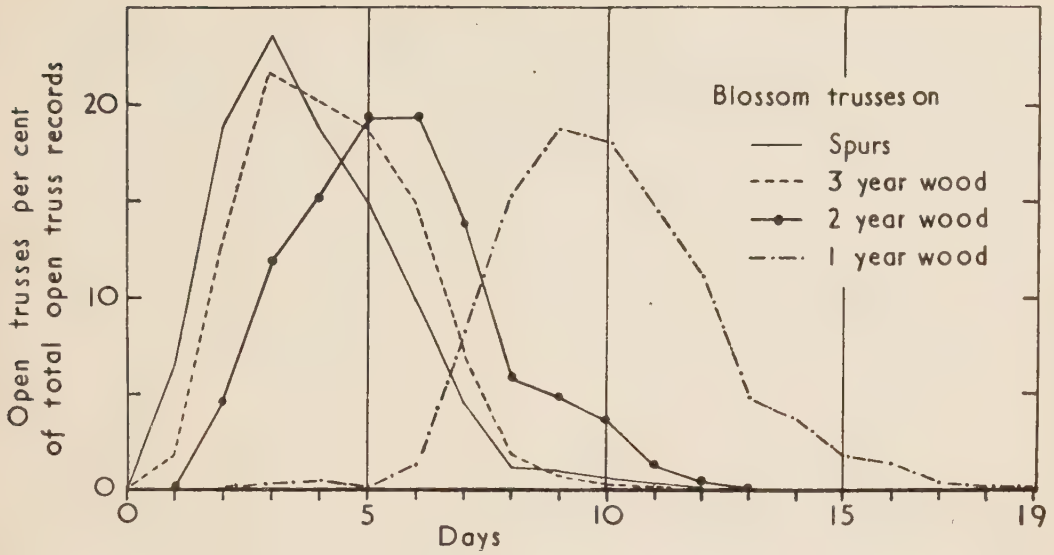


FIG. 3.
Relative periods of opening of blossom trusses on spurs, 3-year, 2-year and 1-year-old wood of Cox's Orange Pippin, 1947.

on 1-year wood was much larger in 1946 than in 1947, when for some unknown reason, axillary blossoms were not very numerous. Even from this diagram, for an abnormally short blossom season, it is clear that if conditions had been unfavourable for pollination during the first 5 days, or if the early blossom had been damaged, the renewal-pruned trees would have been in a more favourable position during the succeeding 10 days than the spur-pruned ones, for the blossoms on spurs had risen sharply to a peak and become more than two-thirds over by the end of five days. Where the conditions for setting are good in the first five days, as in fact they were in this year, there should be ample opportunity for a full crop to set on the relatively short-lasting but more numerous spur blossoms.

The more spread out blossom period may also bring certain difficulties, however, for instance in the correct timing of the " petal fall " sawfly spray. A record of the number of dropped fruits infested by sawfly, expressed as a percentage of total dropped fruit in 1946, showed the renewal-pruned trees to have 5·7 per cent. infested dropped fruits as against 3·5 per cent. for the spur-pruned trees. This difference was significant. Although this had no important effect on the crop harvested in 1946. it might be serious in some years, and a careful check will be kept on the point in future years.

**Crop.**

The figures for crop weight per tree, given in Table I, show that for the two years 1942 and 1943, before the pruning treatments were applied, there were no appreciable differences between the selected

TABLE I.

YIELD, SIZE AND COLOUR OF FRUIT, AS AFFECTED BY ESTABLISHED-SPUR AND RENEWAL PRUNING.

| | Yield (lb. per tree). | | | | Size of fruit. | | Red Coloration (Mean grade value). |
|---|---|---|---|---|---|---|---|
| | Before commencement of treatments. | | After commencement of treatments. | | Mean wt. per 100 apples (lb.) | | |
| | 1942-3. | 1944. | 1945. | 1946. | 1945. | 1946. | 1946. |
| Established-spur .. | 174·8 | nil | 94·6 | 77·7 | 23·8 | 21·4 | 1·6 |
| Renewal .. .. | 171·6 | nil | 99·6 | 129·7 | 25·2 | 19·5 | 2·5 |
| % difference .. .. | *−1·8* | — | *+5·3* | *+66·8* | *+5·9* | *−8·8* | — |
| Significance .. .. | n/s | — | n/s | P<·01 | n/s | P ·01 | P<·05 |

series of trees. As already mentioned, the 1944 crop was nil, owing to frost. The pruning treatments were started in March, 1945, consequently little difference, due to pruning, might be expected in the 1945 crop ; for the shoots left uncut in the renewal-pruned trees in spring, 1945, though they might produce some axillary trusses that spring, would mainly form fruit buds to blossom in 1946.

Actually, little difference was found in the 1945 crop. A 5 per cent. increase, both in amount and size of fruit, in the renewal-pruned trees was not significant. The increase in amount might have

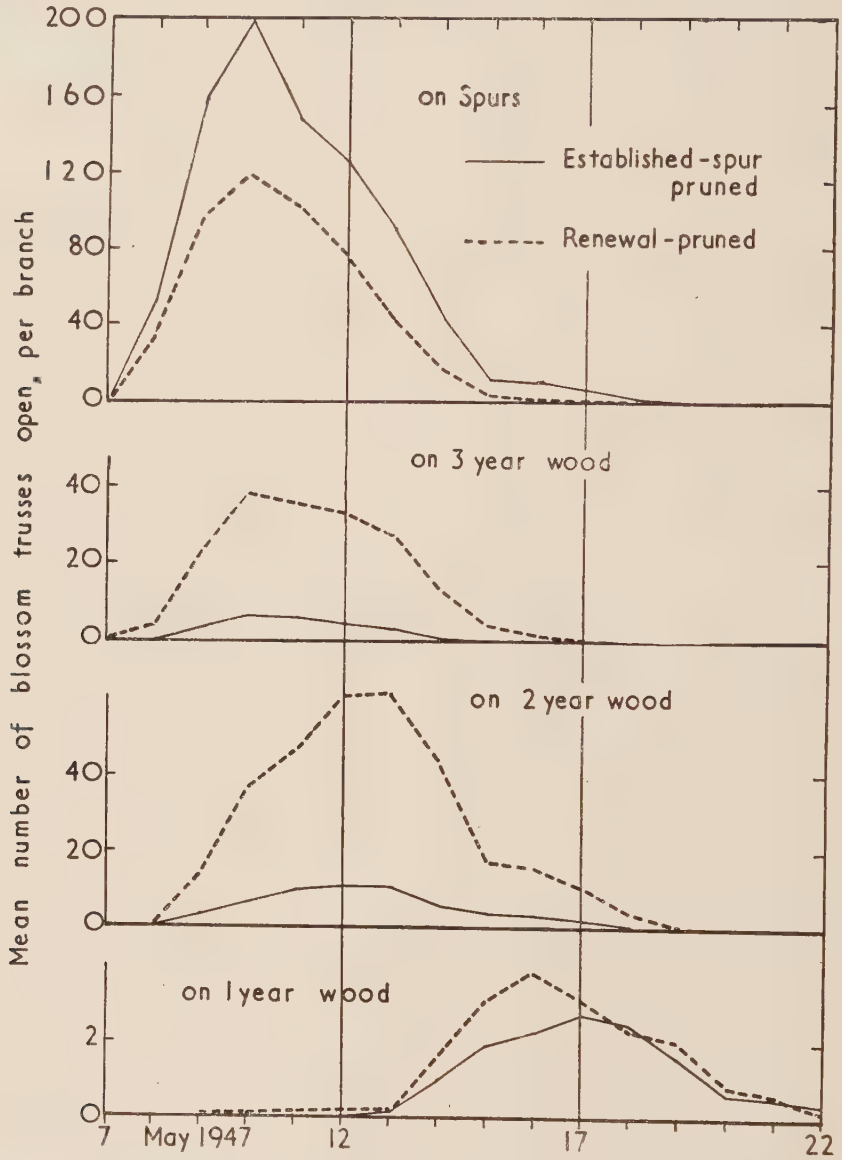


Fig. 4.
Relative amounts of blossom given by Established-spur and Renewal pruning on different kinds of wood, and their relative effective blossom periods.

been larger, however, if petroleum spray damage had not destroyed most of the buds that could produce axillary blossoms.

In 1946 a very interesting contrast is seen, for the renewal-pruned trees had an average of 52 lb. more fruit per tree than the spur-pruned ones—a 66·8 per cent. increase. In this season the apples on the renewal-pruned trees were 8·8 per cent. smaller, as shown by weight per fruit, however ; thus, the difference in number of apples (recorded but not shown) was even greater than the difference in weight. The reduction in size is probably largely due to the increased crop.

A visual colour record of the fruits was made immediately after picking, classifying the appearance of colour into five categories, of which five was the highest. This record showed a significantly greater amount of red coloration in the renewal-pruned trees, than on the spur pruned ones—a difference probably due to the better exposure of the fruits to sunlight.

Thus, in 1946, the renewal-pruned trees produced a much larger amount of better coloured fruit than the others.

It cannot yet be said with certainty whether the highly significant gain of over 60 per cent. in crop weight is due to the presence of more fruit buds on the renewal-pruned trees, or the better setting of fruit upon them, possibly through their spreading over a longer effective blossom period and obtaining better pollination, or avoiding the spring frosts which caused a little damage to early blossoms in 1946. All trees appeared to produce abundant blossom, so the two last-mentioned factors may well be the important ones.

Future years will show whether such differences are consistent, in relation to the varying spring weather conditions.*

**The Labour Aspect.**

The time taken to prune the trees by the two systems has been recorded each year. At present the renewal-pruned trees take rather longer than the others. This is partly because the pruners are less accustomed to the system, but even the experienced ones seem to use rather more time to consider which shoots to cut and which to leave. The time would not be exactly comparable with commercial conditions, in any case, but the record should be of greater value as the experiment gets older. An improvement in technique is also being sought.

**Conclusions.**

Although, as already stated, it is too early to form full conclusions, these preliminary observations suggest that, if the special features of the renewal system are recognized, and care is taken to avoid forms of damage to which the system seems liable, it can, under certain conditions, give considerably better results than the established-spur system, with vigorous trees of varieties such as Cox's Orange Pippin. It remains to be seen whether these differences will continue over a period of years.

Renewal pruning requires careful and intelligent application, and needs adapting to the growth conditions each year to an even greater extent than spur pruning. There may yet be further developments in the technique, especially with regard to the " swingers " (long shoots) which have reached three years old.

The experiment described refers only to mature trees. One of the greatest advantages claimed for renewal pruning is that it promotes early cropping. This point and others in relation to pruning of young trees are under investigation in a series of trials at East Malling, now in their second year.

It is clear that, for the varieties and conditions which it suits, renewal pruning is a very valuable method, and much credit is due to Mr. C. R. Thompson for his careful thinking out and enthusiastic advocacy of the system.

**Summary.**

1. The essential differences between " established-spur " pruning and the " renewal " system are briefly described. The two systems are compared, as applied to vigorous mature trees of Cox's Orange Pippin apple, in an experiment with tenfold replication.

2. Preliminary results during the first two years of the experiment showed renewal-pruned trees to suffer more severely than spur-pruned trees from petroleum spray damage. The importance of avoiding such damage is emphasized.

3. Detailed blossom records showed that the blossoms on 1-, 2- and, to a lesser extent, 3-year-old wood tend to open later than those on spurs. Renewal-pruned trees have more of this younger wood than established-spur trees and thus their effective blossom period tends to be longer. This has favourable effects in giving a greater chance of meeting good pollination conditions and possibly escaping certain forms of frost damage. An unfavourable effect may be increased difficulty of control of apple sawfly.

4. In the second year after commencement of the trial, the renewal-pruned trees had 66 per cent. more fruit than the spur-pruned ones, and the fruit was also better coloured.

5. No full conclusions can yet be drawn, but the renewal system appears very valuable for the conditions which it suits.

* While this paper was in the press, the 1947 crop figures came to hand. In 1947, a favourable year for Cox, the spur-pruned trees had a mean crop of 267 lbs., and the renewal-pruned ones 336 lbs. per tree.

**Acknowledgements.**

The writers wish to express their thanks to Mr. C. R. Thompson, late Assistant Adviser in Fruit-growing to the Kent County Council, for his interest and advice.

Also to the Statistical Section of the Research Station for their help with the planning of the trial, analysing the data and preparing the diagrams, and to Miss B. F. Seymour, who, with her assistants, has carried out the pruning treatments, and whose co-operation has been very valuable.

## References.

Anon. (1946). "Apples and Pears." *Bull. Minist. Agric., Lond.*, 133, 49-61.

Grubb, N. H. (1922). "Winter pruning experiments with apple trees." *J. roy. hort. Soc.*, **47**, 139-62.

Rogers, W. S. (1946). "Growth and cropping of apple trees on Malling rootstocks on five soil series." *J. Pomol.*, **22**, 209-25.

Steer, W., and Moore, M. H. (1941). "Spray damage and apple capsid control by winter petroleum." *Rep. E. Malling Res. Sta. for 1940*, 76-81.

Thompson, C. R. (1941, 1943). "Modern apple tree pruning." First edition, 1941, second (enlarged) edition, 1943. Headley Brothers, London.

*a*

*b*

Fig. 1.

Cox's Orange Pippin tree, pruned by Established-spur method.
(*a*) Before winter pruning.
(*b*) After winter pruning. Note piles of prunings, one year wood on left, older wood on right.

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*a*

*b*

FIG. 2.

Cox's Orange Pippin tree, pruned for the last three seasons by Renewal method.
(*a*) Before winter pruning for third season.
(*b*) After winter pruning for third season. Note piles of prunings, one year wood on left, older wood on right.

# A SOIL SURVEY OF THE NEW BRADBOURNE EXPERIMENTAL ORCHARDS

By A. P. PRESTON and D. J. STANTON*

## Introduction.

The purchase in September, 1938, of Bradbourne Manor with its 200-acre farm, brought the Research Station valuable land for experimental fruitgrowing, comprising several different soil series. Full advantage of this was taken when, in the winter of 1945, new dessert apple plantations were designed and planted to provide experimental material for future years.

Soon after the young trees were planted, the second writer, while on a visit to this country, was invited to survey the soils of the two new plantations and his findings form the basis of this report. The two areas dealt with are known as Churchfields and Larkfield plantations, and at present most

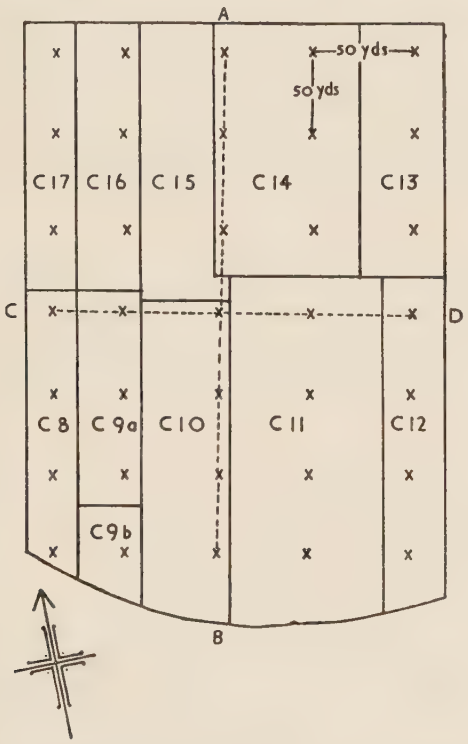


Fig. 1.

Plan of Churchfields plantation showing the positions of soil auger borings (X) and the position of typical sections A-B and C-D drawn in Fig. 2. Experimental plot numbers are shown on this plan.

of the young trees are being given uniform cultural treatment until they are required later for experimental purposes. Some parts of the plantations, however, are already planted with new apple rootstock and apple variety trials, and long term trials designed to show the effects of tree shape and pruning upon the biennial bearing habit have begun.

The soil survey of the south-eastern counties by Hall and Russell (1911) has been followed in recent years by soil surveys using a classification after the American system (Lee, 1931), and readers unfamiliar with modern soil terminology are referred to recent publications by Furneaux (1933, 1935).

* The actual survey of these plantations was done by the second author, of the Cawthron Institute, Nelson, N.Z., during a period of voluntary work at East Malling. The first author is responsible for presenting the results of the survey and other data in this paper.

## Table I.

### Chief Characters of some of the Soil Series on the Lower Greensand in Kent.*

| Soil series. | Texture range of surface soil. | Geological origin. | Mode of soil formation. | Natural drainage. | Topographic position. | Main distinguishing features of soil profile. | Growth shown by fruit trees. |
|---|---|---|---|---|---|---|---|
| Bearsted | Sand-sandy loam. | Folkestone Beds. | Sedentary : surface eroded. | Good to excessive. | Elevated and sloping. | A shallow topsoil over highly-coloured yellow to orange loamy sand which passes into Folkestone Beds at 2 ft. or less. | Bad to average. |
| Lowlands | Loamy sand-loam. | Folkestone Beds. | Colluvial. | Good. | Flat to gently sloping on lower slopes and foot of hills. | Deep uniform greyish-brown sandy-loam material. | Average to good. |
| Willesborough | Pebbly loamy coarse sand-sandy loam. | Valley gravel. | Alluvial. | Excessive. | Gently sloping slightly elevated. | A shallow light soil over river gravel. | Bad. |
| Barming | Loamy sand-loam. | Pleistocene sandy loam (usually mapped as valley gravel). | Alluvial. | Good. | Level to very gently sloping. | A somewhat gravelly harsh sandy loam, reddish brown in colour and without any obvious signs of soil horizonation. | Poor to good. |
| Malling | Sandy loam-loam. | Pleistocene sandy loam overlying ragstone. | Alluvial material over sedentary Hythe Beds. | Good. | Level to gently sloping. | A reddish-brown light textured drift overlying ragstone, with a dark chocolate-brown, sticky horizon at the junction. | Good. |

* Reproduced by courtesy from Ministry of Agriculture and Fisheries Bulletin No. 80, 1934.

This survey was made of the soil profiles on both plantations, auger borings being made to a depth f 5 ft., where possible, on a 50-yard grid, and the data obtained from the survey have been arranged nd classified in the same way as the soils of the Lower Greensand formation (Bane and Gethin Jones, 934).

**hurchfields Plantation.**

This plantation is situated between 100 and 110 ft. above sea level on a gentle northern slope nd lies on a heavy loam stretch of Pleistocene alluvial drift overlying the Hythe Beds division of the ower Greensand. The drift, which is a sandy loam at the surface, but which stiffens with depth ) a sandy clay loam, is characterized by a heavy and highly glauconitic horizon immediately above nd lying in contact with the Hythe Beds, the sticky layer being locally called the " pug ". This soil ; typical of the Malling Series, on which lie most of the older plantations of the Research Station. he Barming Series, of which large areas exist in the district, is a drift of similar origin but remains of andy loam texture throughout and lacks the " pug " layer (Table I).

Frequent variations from yard to yard in the thickness and concentration of this pug horizon re a feature of the Malling Series. Thus, in some places, there may be nearly 5 ft. of a warm brown andy loam soil which passes into a fairly sharply defined pug horizon some 6-12 in. in depth. At thers, the pug horizon will approach much nearer to the surface and the sandy loam soil fades gradually

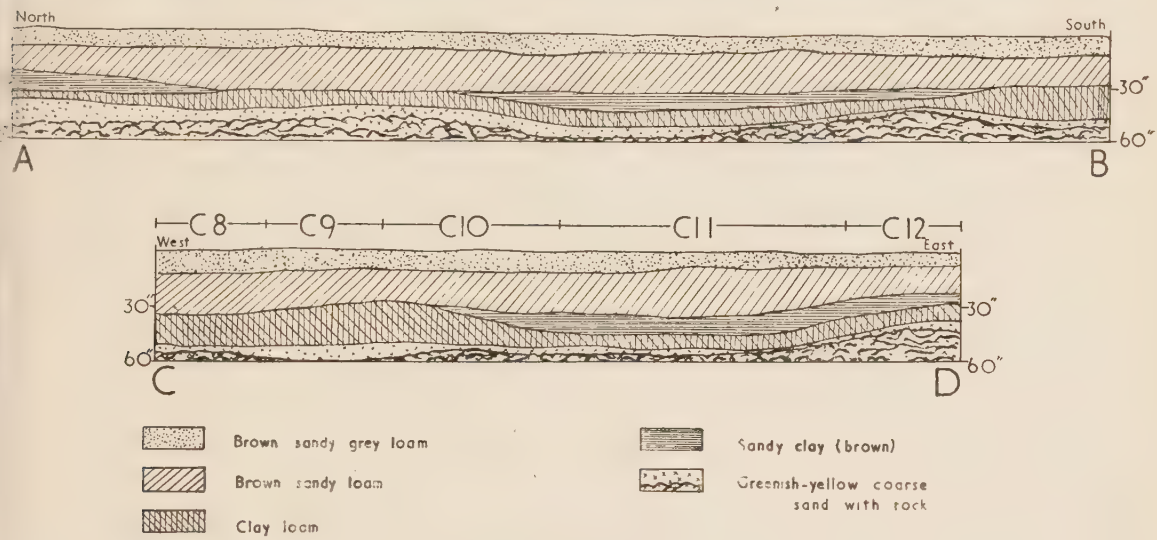


Fig. 2.

Typical Sections through Churchfields plantation from auger borings. Position of experimental plots is shown in Section C-D.

nto it, producing a sandy clay loam. In the pug itself bright green grains of unweathered glauconite contrast with the rather dark brown of the pug.

The horizon of the clay loam in this plantation varied between 6 and 20 in. in thickness and lay n the hassock or often directly on the ragstone. The ragstone, the grey crystalline limestone of he Hythe Beds, and the hassock, the buff coloured calcareous sand with which it is interbedded, normally vary considerably in their depth from the surface. In this plantation the nearest approach f hassock or ragstone to the surface was 36 in. and in only one boring was neither encountered before reaching a depth of 5 ft.

The soil in this plantation contained practically no stones, but in a few instances some were ound at 24 in. from the surface. They did not appear continuous or extensive, the almost constant depth of 24 in. being the only noticeable fact about them.

A plan of this plantation is shown in Fig. 1 and typical cross sections of the plantation along ines A-B and C-D are reproduced in Fig. 2 as soil profiles obtained from the auger boring data. It will be seen that generally the plantation is sited on a uniform stretch of soil and, owing to its depth nd the fairly high clay content of the subsoil, moisture retention should be good, whilst drainage of the Malling Series is excellent throughout. The exact position of the auger borings has been recorded (see Fig. 1), so that tree performance on each Plot can be correlated with soil depth and structure in future years.

Analyses of random soil samples from the plantation showed the pH to vary between 7·0 and 7·8. Although available potash was low for the whole area, it was higher for the northern half of the plantation than the south ; this may possibly be due to the application of fertilizers during recent years, especially on the northern half of the plantation which was an old hop garden until six years ago. Available phosphate was found to be plentiful, whilst magnesium was low. Calcium carbonate may be present in this type of soil as hard unweathered ragstone in the subsoil and weathered ragstone in the surface soil. As calcium may be significant in connection with iron or other minor element deficiencies, the figures obtained for calcium in the analysis may be valuable in the interpretation of the performance of trees on this plantation in the future.

**Larkfield Plantation.**

This plantation varies in height from 85-95 ft. above sea level with sharp downward slopes on the south, east and west sides and a slight valley in the centre of the plantation running southwards ; this is shown by a diagrammatic cross section in Fig. 3. The plantation lies on the outcrop of the Folkestone Beds, the uppermost division of the Lower Greensand. The Folkestone Beds consist of pale yellow and buff coloured current bedded marine sands. On the twin hillocks (Fig. 3) there are the remains of a Valley Gravel deposit lying on a denuded river terrace. This is the fringe of a considerable area of gravel which stretches northwards for over a mile. The river terrace represents the former floor of the stream valley upon which was deposited a gravel consisting chiefly of flints and pieces of

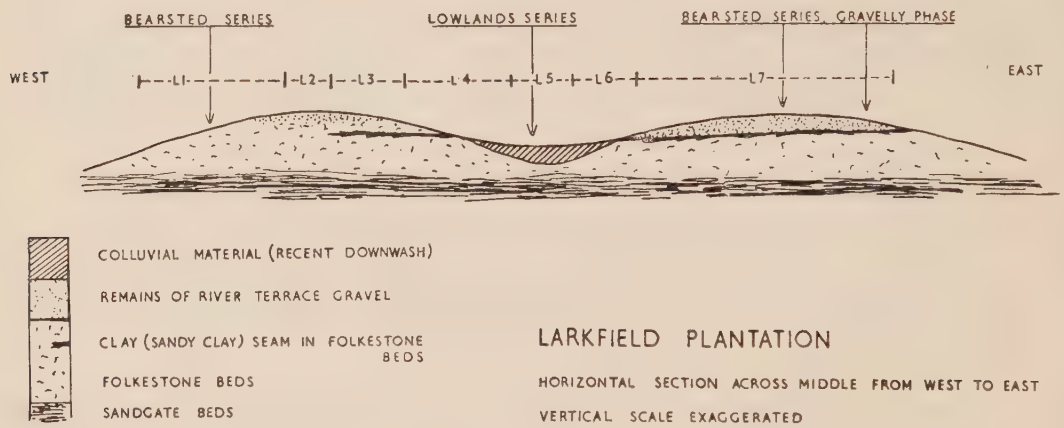


Fig. 3.

Diagrammatic Cross-Section of Larkfield plantation showing the position of experimental plots in relation to the soil series.

chert from the Hythe Beds. Subsequent uplift of the whole countryside rejuvenated the rivers and caused them to lower their valleys, so that only vestiges of their original floor remain. The plantation lies right on the fringe of one of these gravel remains.

The cap of gravel in the plantation is not more than 2 ft. thick and it is so completely mixed with Folkestone Beds material that it can scarcely be regarded as giving rise to a separate soil series. On the twin hillocks, therefore, the soil belongs to the Bearsted Series, in which the top soil is typically a brownish grey loamy sand showing a faint degree of podsolization. Below this, at a depth varying from 10 to 30 in., is the unweathered bright yellow to orange sand of the Folkestone Beds. The soil is shallowest on the slopes of the hillocks where it has undergone considerable erosion. On the more or less flat hilltops erosion has been less and it is here that the soil is contaminated with the remains of the Valley Gravel. The gravel is, however, not sufficiently thick to justify its separation into the Willesborough Series, so it must be regarded instead as a gravelly phase of the Bearsted Series.

The Folkestone Beds frequently contain thin seams of a more clayey material. These contrast with the typical sand of this formation. A heavier seam of this type outcrops on the sides of the hillocks in this plantation. Thus, instead of the yellow sand typical of the Bearsted Series, there is a sandy loam or, in places, a sandy clay loam of a yellowish brown colour. This would retain more moisture and plant foods than the very open textured soil of the ordinary Bearsted Series.

In the slight valley and around the lower southern slopes of the hillocks (the latter mainly outside the plantation) downwash has collected as a result of long continued erosion. Here the loamy sand soil is much deeper than that of the Bearsted Series. It is of a warm brown colour and shows little

variation throughout its depth. It is typical of the Lowland Series, on the soils of which most kinds of fruit trees grow and crop well, in contrast to soils of the Bearsted Series, which generally give poor vigour and unhealthy bark symptoms.

The plantation lies not far from the southern or lower margin of the Folkestone Beds, so that the sandy clay of the underlying Sandgate Beds outcrops a little southwards. The latter are impervious to the passage of water and the result is to throw out a certain amount of spring water into the subsoil of the land to the south ; but on the plantation itself drainage appears to be free throughout and the soil of the Bearsted Series in particular has little capacity for water retention, except where the clay seam outcrops. That of the Lowlands Series, however, has a much better retentive power owing to its greater depth of loamy material.

The important features of some of the soil series in question are shown in Table I, reproduced from the survey of the fruitgrowing areas on the Lower Greensand in Kent (Bane and Gethin Jones, 1934).

A plan view of the plantation is shown in Fig. 4 giving the positions of the auger borings, while Fig. 3 illustrates the general topography of the plantation. Cross sections of the plantation showing soil profiles drawn from the auger boring data are shown in Fig. 5. Section G-H shows the soil depth and formation on the east hillock, being soil of the Bearsted Series. Section L-M through the west hillock is similar and is not shown. A section through the soil of the Lowlands Series J-K, shows a considerable depth of loamy sand colluvium from the eroded slopes of the twin hillocks.

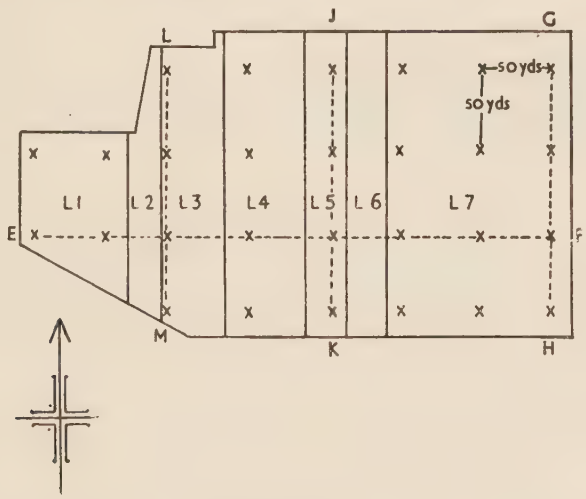


FIG. 4.

Plan of Larkfield plantation showing the positions of soil auger borings (X) and the position of sections E-F, G-H and J-K drawn in Fig. 5. Experimental plots are shown on this plan.

The soil analyses of this plantation showed a pH varying from 6·1 to 6·7 and, while available potash was low or very low, yet it was higher than for the south half of Churchfield plantation. The data were insufficient to classify the magnesium results, but they tend to be on the low side. In view of the low potash and possibly low magnesium, the relatively high available phosphate may result in deficiencies of potash and magnesium occurring more readily.

**Discussion.**

To the fruit tree experimenter the soil formation and depth on the Churchfields plantation is almost ideal, giving a uniform stretch of soil with little variation in depth or structure. It is known from experience that the Malling Series gives vigorous healthy growth to fruit plants, and that drainage is excellent ; yet the clay content of the subsoil provides for adequate moisture retention.

The Larkfield plantation on the other hand, with its varying depths of soil and continuous erosion provides many problems, both in the management of the trees and in the interpretation of experimental results, and considerable contrasts in tree performance may be anticipated. The gravelly phase of the Bearsted Series on the hillocks may provide an opportunity for the research workers here at East Malling to study some of the problems found on other gravelly soils, e.g. in Essex. The trend in modern fruitgrowing is to plant upon hillsides to lessen the risk of radiation frosts, and it is already evident that special precautions in cultivating and cover cropping this plantation must

be taken to avoid serious erosion. This plantation may serve to formulate new cultural techniques for the hillside plantations in this country.

In the diagrams it will be seen that the newly-planted experimental Plots have been given index letters and numbers ; and it is hoped that this report will serve as a useful reference when future reports are issued on the experiments on these Plots showing the respective soil series on which they are planted.

Some of the trials at present under way on the Churchfields plantation are replicated on the Larkfield plantation and, although it is intended to manage both plantations according to the needs of their respective soils, it will be interesting to compare trees of known history upon two such widely differing plantations on three soil series.

**Acknowledgements.**

Mr. D. M. Hacking, a voluntary worker at East Malling, rendered valuable assistance to the second author in carrying out the survey. The first author is especially indebted to Mr. B. S. Furneaux for much assistance in deciding the correct soil series on the two plantations and for allowing him to use many of his own technical notes on the results of the survey, in order that the permanent record may be of value to future workers.

Dr. N. H. Pizer of Wye College kindly carried out the chemical analyses of the soil samples.

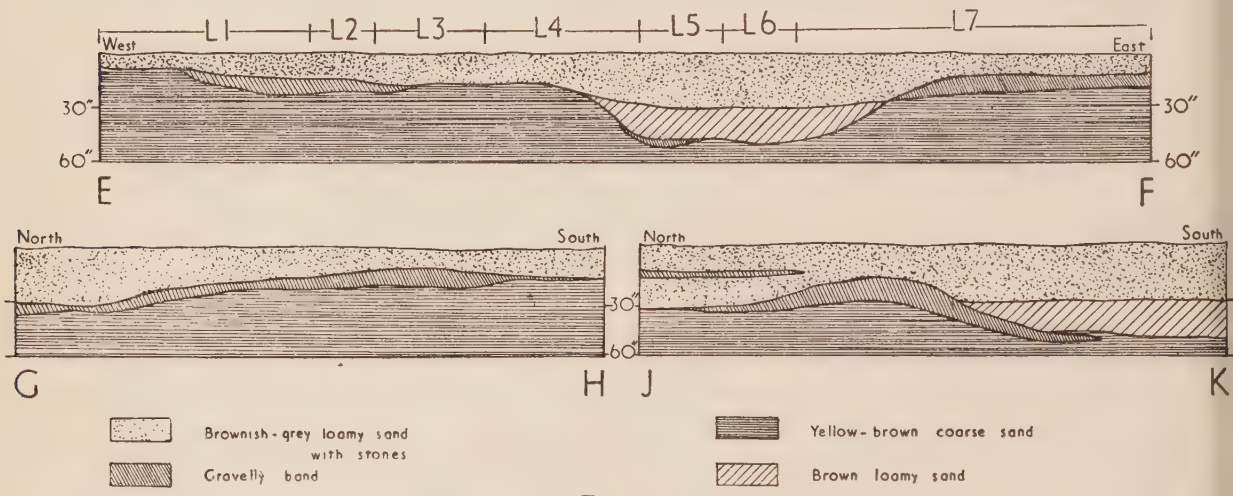


FIG. 5.

Showing three cross-sections of Larkfield plantation from auger borings. Position of experimental plots is shown in section E-F running across the plantation. Section G-H shows soil of the Bearsted Series present on the twin hillocks. Section J-K shows soil of the Lowlands Series with 30 in. of colluvium from the eroded hillocks.

Mr. T. N. Hoblyn and Dr. W. S. Rogers have both advised the first writer upon the presentation of this paper and their help is gratefully acknowledged, whilst Miss J. M. S. Thom has kindly prepared the diagrams for publication.

**Summary.**

1. Two new plantations of dessert apples called Churchfields and Larkfield have recently been planted on the new Bradbourne land to meet experimental needs for future years.

2. A detailed soil survey was carried out by means of auger borings on a 50-yard grid and soil profiles were determined, to a depth of 5 ft. wherever possible.

3. The Churchfields plantation was found to be a very uniform stretch of Pleistocene alluvial drift overlying the Hythe Beds division of the Lower Greensand. The soil, which is a sandy loam at the surface, but which stiffens with depth to a sandy clay loam, is typical of the Malling Series.

4. The Larkfield Plantation lies on the outcrop of the Folkestone Beds, the uppermost division of the Lower Greensand. The soil on the twin hillocks was found to belong to the Bearsted Series, but on the flat hilltop, where erosion has been less, the soil is contaminated with the remains of a Valley Gravel deposit, and must be regarded as a gravelly phase of the Bearsted Series. Around the southern slopes of the hillocks and in the slight valley separating them, downwash has collected as a result of long-continued erosion, it is of a warm brown colour and shows little variation, typical of the Lowlands Series.

## References.

LEE, LINWOOD L. (1931). "The Possibilities of an International System for the Classification of Soils. *J. S.-E. Agric. Col.*, **28**, 65-114.

FURNEAUX, B. S. (1933). "In Quest of the Ideal Fruit Soil." *H.E.A. Yearbook*, **2**, 67-76.

——— (1935). "Selection of Soils for Dessert Apple Growing." *Scient. Hort.*, **3**, 42-54.

HALL and RUSSELL (1911). "Agriculture and the Soils of Kent, Surrey and Sussex." Board of Agriculture, London.

BANE, W. A. and GETHIN JONES, G. H. (1934). "Fruitgrowing Areas on the Lower Greensand in Kent." *Bull. Minist. Agric., Lond.*, 80.

# "GREEN BLOTCH", AN ABNORMAL TISSUE OF APPLE FRUITS, PROBABLY ASSOCIATED WITH SPRING FROST

By IRENA MODLIBOWSKA

In the autumn, 1945, a peculiar abnormality was observed on fruits of several different varieties of apple at East Malling. This took the form of green blotches, always at the calyx end of the fruit, sometimes occurring singly, but more usually forming a broken ring about 0·5 cm. wide and 4-5 cm. in diameter, with the eye in the centre. These green blotches had a deeper green colour than the rest of the fruit and formed sunken areas (Fig. 1). Both of these characteristics became accentuated with the ripening of the fruit, as it changed colour, for the blotches always remained green and sank deeper. This persistence of the green colour and the occurrence of the affected areas at the calyx end of the fruit, are somewhat similar to a kind of frost injury to young apples described by Rose *et al.* (1933). According to these authors, " Badly damaged specimens are nearly always distorted at the blossom end, may have only a few poorly developed seeds or none at all, and usually show in cross or longitudinal section a blotchy or streaked browning in the flesh underlying the green areas."

At East Malling, no such severe damage was observed. The fruits with green blotches were not distorted at the calyx end. They had less good seeds than the unaffected, and a correlation (of $-0{\cdot}328$) between severity of damage and number of seeds was statistically significant ($P<0{\cdot}02$). No blotchy or streaked browning in the flesh underlying the green areas was ever observed at East Malling. It is not excluded that this might have been a secondary trouble.

Although these two kinds of fruit blemish are similar in some respects and differ in others, it is difficult to state without histological examination of both kinds of tissue, whether the differences between them are essential or due only to the degree of injury.

Since no published description of trouble identical to that observed at East Malling has been found, and the phenomenon described by Rose *et al.* (1933) was not named, it is proposed to name the phenomenon here described—" Green Blotch ".

The variety that suffered most was Ellison's Orange. At East Malling, about 65 per cent. of the fruits from cordons and many of those from two half standard trees frameworked with this variety were affected in 1945, but the occurrence of the green blotches on the fruit was not confined to East Malling. Even at the fruit shows of the Royal Horticultural Society in 1945 several samples of Ellison's Orange from different parts of the country were seen to be so affected.

TABLE I.

APPLE VARIETIES SHOWING GREEN BLOTCH ON FRUITS IN 1945.

Ellison's Orange, heavily affected.
Aromatic Russet, medium affected.
Barnack Beauty, ,, ,,
Hubbardstone Nonsuch, medium affected.
Ohinemuri, ,, ,,
Arthur Turner, slightly affected.
Bridget, ,, ,,
Charles Ross, ,, ,,
Coo's River Beauty, ,, ,,
Crawley Beauty, ,, ,,
Crofton, ,, ,,
Democrat, ,, ,,
George Carpenter, ,, ,,
Gooseberry Pippin, ,, ,,
Grimes Golden, slightly affected.
Hitchin Pippin, ,, ,,
James Grieve, ,, ,,
Jonathan, ,, ,,
Joybells, ,, ,,
Lord Burghley, ,, ,,
Lane's Prince Albert, ,, ,,
Mercer, ,, ,,
Monarch, ,, ,,
Opalescent, ,, ,,
Royal Jubilee, ,, ,,
Signe Tillisch, ,, ,,
Winter Majetin, ,, ,,

A collection of 195 apple varieties fruiting at East Malling in 1945 was examined and 27 of them (14 per cent.) were found to show Green Blotch (Table I). In addition to the fruits affected by Green Blotch, 9 varieties (4 per cent.) showed radial cracks (Table II) and 6 varieties (3 per cent.) frost rings on fruit (Table III). Frost rings occurred sometimes on the same varieties as Green Blotch

Barnack Beauty and Joybells) and occasionally together on the same fruit and even in the same position round the calyx (Barnack Beauty). On the variety Democrat, radial cracks and Green Blotch occurred together, even on the same apple.

TABLE II.

VARIETIES WITH FRUITS SHOWING RADIAL CRACKS IN 1945.

| | |
|---|---|
| Devonshire Quarrenden, | heavily affected. |
| Diamond, | ,, ,, |
| Gravenstein, | ,, ,, |
| Onyx, | ,, ,, |
| Pearl, | ,, ,, |
| The Premier, | ,, ,, |
| Wagener, | medium affected. |
| Democrat, | slightly affected. |
| Thurso, | ,, ,, |

TABLE III.

VARIETIES WITH FROST RINGS IN 1945.

| | |
|---|---|
| Early Victoria, | medium affected. |
| Barnack Beauty, | slightly affected. |
| Gloucester, | ,, ,, |
| Joybells, | ,, ,, |
| Pearl, | ,, ,, |
| Pott's Seedling, | ,, ,, |

In 1946, at East Malling, only a few Green Blotches were found, on fruits of Ellison's Orange, Rival and Wagener. They were neither very conspicuous in colour nor as much sunken as in the previous year. Much better examples were found at the fruit shows of the Royal Horticultural Society on several samples of Ellison's Orange from Kent, Surrey and Hertford, and on Charles Eyre. These varieties showed single, often partial, broken rings of blotches. On Taylor's Seedling, however, two incomplete concentric rings of green blotches were very pronounced. Blotches of the inner ring were lying between sepals. They were small and dark green. Blotches in the outer circle, separated about 0·5 cm. from the inner one, were larger, lighter in colour and situated opposite the corresponding ones in the inner circle. A few green blotches were also noticed on Golden Spire and Newton Wonder.

Histological examination has shown that an abnormal, greenish white, spongy tissue (Fig. 2) occurred in the Green Blotch areas underneath the epidermis and the 4-5 hypodermal layers. It was soon established that it was not a parasitic organism, and it was also quite distinct from the normal callusing following frost cracking (Modlibowska, 1946).

It consisted of elongated cells with thick, hyaline external walls and thin internal ones between the cells. They divided transversely, forming hyphae-like threads branching and often changing their direction of growth (Fig. 3*a* and *b*). The tissue built in this way was very irregular, entangled and contained large air spaces. In a radial section this tissue had often a fan-like shape (Fig. 4) while in transverse section it was more elongated. This was determined by the direction of the internal cracks, which were later filled by abnormal callus. These cracks occurred usually between vascular bundles. They were very shallow, spreading widely towards the epidermis. As a result the neighbouring ones often joined, forming a ring. Where there was only a circular lifting of the skin, a thin layer of this abnormal tissue was formed, and so the green blotches were much paler and less sharply delimited.

Because the skin (epidermis and hypodermis) remained intact, conditions of high humidity prevailed in the cracked spaces and favoured regeneration of the tissue. Callus was formed from all the surfaces of the wound, but probably mostly from the hypodermis (Fig. 5). This is also supported by the fact that, when in an over-ripe Ellison's Orange the skin peeled readily from the cortex, the spongy tissue usually lifted with it.

The Green Blotch tissue contained much chlorophyll, particularly in the cells closer to the skin. In over-ripe yellow apples the spots were still green, as the chlorophyll persisted both in the hypodermis and in the underlying tissue, probably masking the yellow pigment. It did not mask, however, the red pigment observed in some of the hypodermal cells of Ellison's Orange. Thus, there may be a factor that prevents the disintegration of chlorophyll in the Green Blotch tissue, although this process is taking place in the normal surrounding cells.

In 1946, a somewhat similar abnormal tissue was observed in fruitlets developed from artificially frozen flowers of Sunset and McIntosh Red. The skin of the flowers became loose after freezing, but soon healed normally, except beneath the sepals. In this region, about 3 to 4 weeks after freezing some spongy tissue was found in a few scores of fruitlets dropping at that time. In this case the spongy tissue occurred only in those parts of the fruitlet where growth is not rapid, namely in the sepals, and at their base. In other parts of the fruitlets underneath the hypodermis, normal callus was formed which soon could not be distinguished from the normal tissue.

The Green Blotch tissue resembles somewhat that of apple tufts which are white, cotton-like outgrowths of tissue on carpel walls and seeds. According to Sorauer (1921), formation of this tufted tissue is due to an abnormally high water and nutrition supply at the time of the building of the carpel walls. Tufts were observed by the writer in the apple variety Woolbrook Pippin at the same time as Green Blotch in Ellison's Orange. In both, this abnormal tissue originated following internal cracking of apple tissue, namely, cortex in green blotches or parchment-like carpels in the case of tufts. Both developed in high humidity conditions, but while the apple tufts, completely deprived of light, contained leucoplasts only and were covered with wart-like protuberances (Carpenter, 1924), the tissue of Green Blotch was rich in chloroplasts, particularly in the outer layer adjoining the hypodermis, and had no protuberances.

TABLE IV.

SCREEN FROST NIGHTS IN RELATION TO GREEN BLOTCHES.

| Full bloom. | Screen frosts. | Green blotches. |
|---|---|---|
| 12th-15th April, 1945 | 24th April—29° F.<br>30th April—30° F.<br>1st May—30° F.<br>2nd May—29° F. | Frequent on some varieties. |
| 28th April-1st May, 1946 | 15th May—30° F.<br>17th May—31° F. | Scarce. |

The present study shows that Green Blotch originates from an internal crack in the cortex. Such cracks may be caused by low temperature (Modlibowska, 1946). In the year 1945, when the Green Blotch occurred frequently, some slight screen frosts of 29-30° F. were recorded at East Malling on four nights during the second and third week after full blossom of most apple varieties (Table IV). In 1946, however, only two frosty nights with screen minimum of 30 and 31° F. occurred at East Malling and in that year Green Blotches on apples appeared here only rarely. Simultaneous occurrence of Green Blotch with known symptoms of low temperature injury and their occurrence in frost pockets, supports this possibility, as also does the resemblance of this phenomenon to the frost injury described by Rose *et al.* (1933). The formation of an abnormal tissue instead of a common type of callus may possibly be determined by the stage of the tissue following the split, whether or not it is still actively dividing.

The fact that Ellison's Orange, considered relatively resistant to spring frost, was most affected by Green Blotch does not eliminate the possibility of a relation between this phenomenon and low temperature. On the contrary, the ability of Ellison's Orange fruits to undergo internal splitting of the cortex without damage to the skin, may afford a valuable contribution to the understanding of some factors influencing varietal resistance to frost ; e.g. this may be connected with the withdrawal of water from the cells to the area beneath the hypodermis, leaving the cell sap more concentrated. An important factor in the successful healing of the internal cracks appears to be the elasticity of the skin, which does not crack following damage by frost and so protects the injured tissue below and provides conditions of high humidity favourable to regeneration of tissue to fill the wound.

**Acknowledgements.**

My grateful thanks are due to Dr. A. B. Beakbane and to Dr. W. Filewicz for their helpful suggestions and stimulating interest they have shown during the investigation. I wish also to thank Dr. W. S. Rogers and Mr. T. N. Hoblyn for valuable criticism of the paper and Miss E. C. Thompson for kindly taking the photographs.

**Summary.**

A peculiar blemish at the calyx end of apple fruits was observed in autumn, 1945 and 1946. Many varieties were affected, but Ellison's Orange suffered most. The blemish was in the form of green

Fig. 1.
Green Blotch on fruits of Ellison's Orange.
($\frac{3}{4}$ of the normal size.)

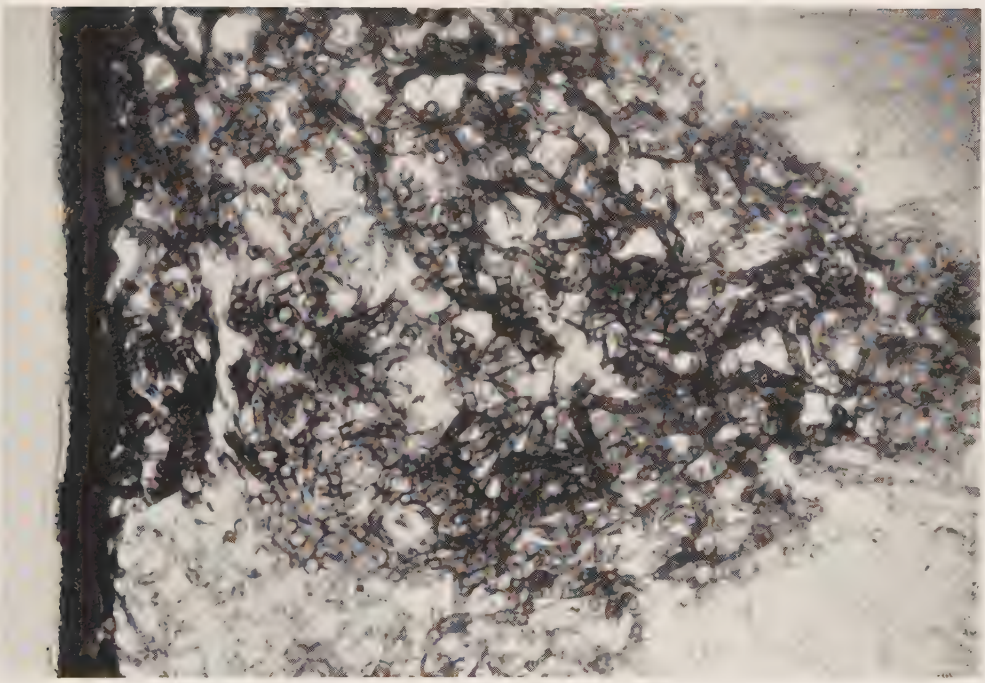

Fig. 2.
Spongy tissue underneath the hypodermis of Green Blotch.
($\times 90$.)

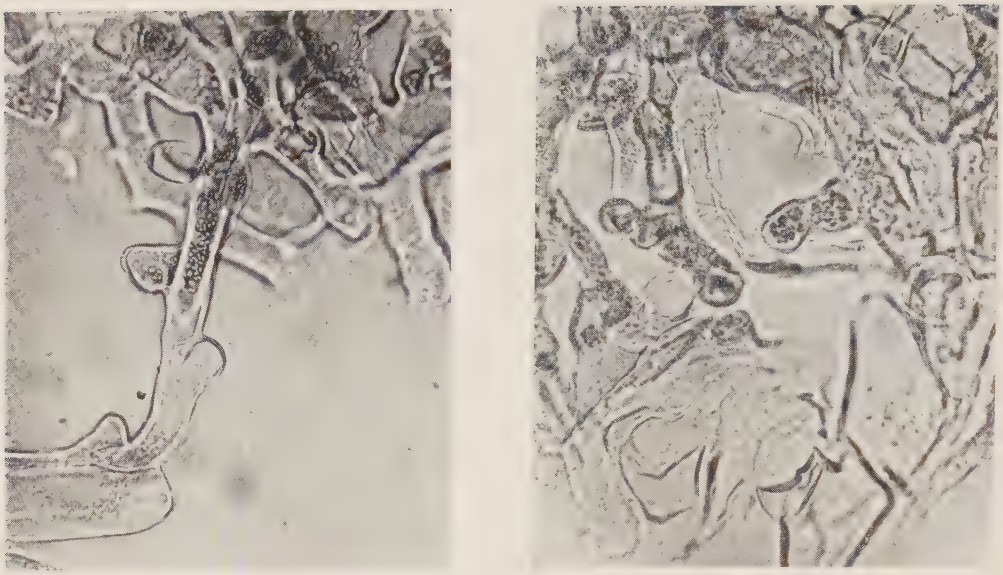

FIG. 3.

(a) (b)

The abnormal cell-growth of the Green Blotch tissue. (×250.)

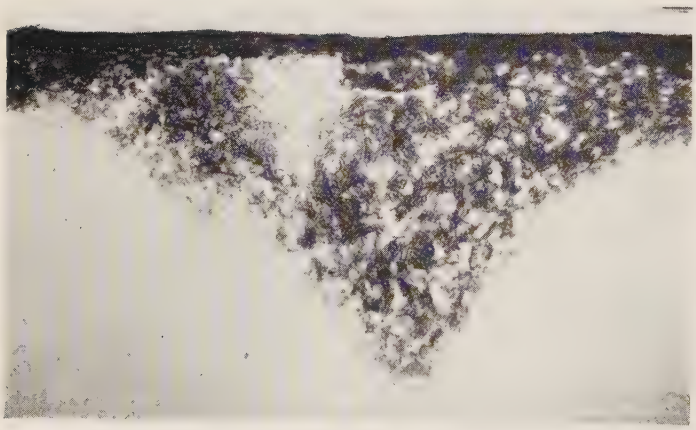

FIG. 4.

Radial section of apple cortex showing the fan-shaped distribution of Green Blotch tissue. (×32.)

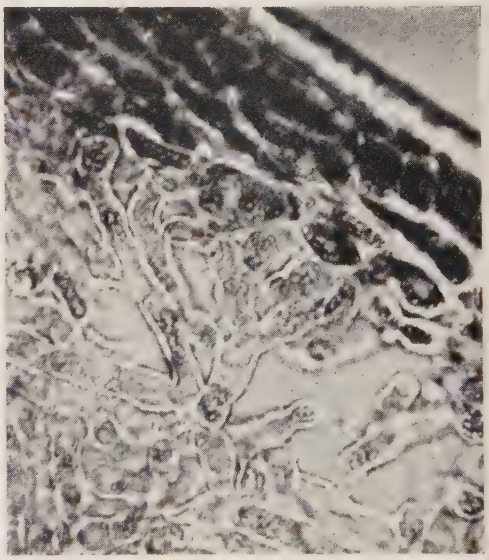

FIG. 5.

The abnormal callus growing out of the hypodermis. (×250.)

otches and resembled to some extent symptoms of frost injury to young fruits described by Rose *al.* (1933). Underneath the hypodermis of the green blotches internal cracks were observed. These ere filled with an abnormal, spongy tissue, consisting of thick hyaline-walled, elongated cells with ry large air spaces. Somewhat similar tissues were observed in sepals of artificially frozen apple owers and in apple tufts. The possible origin of Green Blotch and its relation to low temperature discussed.

## References.

ARPENTER, C. C. (1924). "Apple tufts." *Bot. Gaz.*, **78**, 414-23.

IODLIBOWSKA, I. (1946). "Frost Injury to Apples." *J. Pomol.*, **22**, 46-51.

OSE, D. H., BROOKS, C., FISHER, D. F., and BRATLEY, C. O. (1933). "Market Diseases of Fruits and Vegetables. Apples, pears and quinces." *U.S. Dept. Agr. Misc. Publ.* 168.

ORAUER, P. (1921). *Handbuch der Pflanzenkrankheiten.* Band 1, 412-24.

# DEVELOPMENTS IN THE ISOLATED BLOCK SYSTEM FOR RAISING STRAWBERRY RUNNERS

By W. S. ROGERS

The Isolated Block System of strawberry propagation, devised to combat the spread of virus diseases and maintain healthy stocks has proved so effective in practice that it has passed into general use before very much experimental evidence has been published. Its use was, in fact, an essential part of the Nuclear Stocks Scheme, and it is now one of the requirements for the Special Stock Certificate of the Ministry of Agriculture.

The laying of the runners into small isolated blocks, as specified in the full technical description of the system (Rogers and Buttfield, 1944) is, however, a laborious business, which naturally increases the cost of runner production. From the outset, therefore, methods which may be easier and more economical of ground and labour, while at the same time fulfilling the essential requirements, have been sought for.

The requirements, dictated by the nature of the viruses and insects which it is necessary to overcome (Harris, 1937 ; Massee, 1935 ; Rogers *et al.*, 1939), are that it must be possible throughout the season (and especially in the autumn) to see and remove infected plants and all their runners without their having come into contact with the remaining plants. Several experiments have been made, comparing various runner raising methods which fulfil these requirements of retaining isolated blocks and allowing effective inspection for roguing purposes. War time conditions have prevented the full development of these investigations, which involve not only practical problems but interesting questions of plant competition and ecology ; but it now seems an appropriate moment to review briefly the results of three experiments. Following this, some general considerations and suggestions will be discussed.

## Experimental Comparisons of Runner-raising Methods.

**Experiment I.** In this preliminary experiment, made as long ago as 1933, a comparison was made between the long-established alternate-row system of runner laying, and 4 types of isolated block including one in which the runners were spaced, and thus limited in number. The experimental material was Royal Sovereign M.35, arranged in 5 replicate blocks 12 ft. × 6 ft. The parent plants were planted in March, 1933, all in rows 3 ft. apart, at various spacings in the row as specified in Table I and Figs. 1-3. The runners were laid in by hand, as they formed, keeping clear alleys between blocks. In Method 2 the runners were spaced at about 3 in. apart, as they formed, and when the block was filled at this spacing all further runners were cut off. In the other treatments no limitation was attempted and all runners that could root in the area of the block were allowed to do so (the normal commercial practice). The runners were lifted on 13th October, and divided into 3 grades as follows. Grade 1, plants with good crowns and roots, and leaves more than about 4 in. long. Grade 2, plants with leaves between 2 in. and 4 in. and roots suitable for planting. Grade 3, smaller plants, normally unmarketable ; these were discarded. The results, translated into thousands per acre, are given in Table I (the records of Grade 3 are omitted).

*Results.* It can be seen from Table I that the greater the number of parent plants, the greater the number of runners per acre. Thus the old alternate row method gives the highest yield per acre but this does not provide isolated blocks. The six-plant blocks come next, and the 4-plant blocks last. The limited runner 4-plant blocks naturally come last of all ; it can be seen, however, that their loss is all in second size plants. The slightly wider spacing of Method 3 compared with Method 1 has not resulted in any appreciable difference in total number of runners. A small decrease in number of first size runners is offset by an increase in second size plants, and is unlikely to have any connection with the wider spacing. It will be noted that the wider spacings (Methods 1 and 3) give more runners per parent and less runners per acre than the closer spacings (Methods 4 and 5).

The division into grades shows that wide spacing of parents and spacing of runners both give a higher proportion of first size plants. In practice, however, both sizes 1 and 2 were of good commercial size, and good planting quality. Other work has shown that all runners large enough to become established will crop equally well from the second year onwards. It is only where runners are required for forcing, or to crop in the first season that it pays to select the largest plants (Rogers, 1938). The figure of nearly 50 runners per parent plant is larger than is normally found in commercial practice and reflects the greater care that can be given to small experimental plots.

FIGS. 1-3.—Runner arrangements in Trial 1.

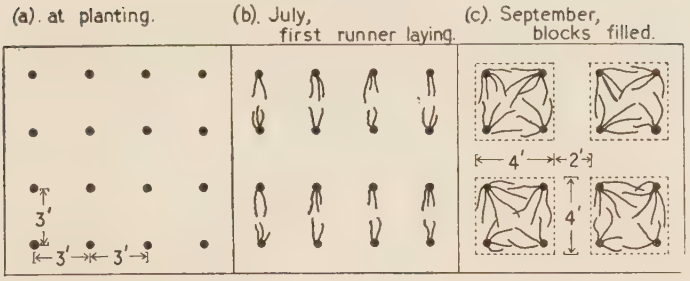


FIG. 1.—Four parent plants in 3 ft. square, as in Methods 1 and 2. Method 3 was similar, with plants 3 ft. 6 in. and 2 ft. 6 in. alternately in the row.

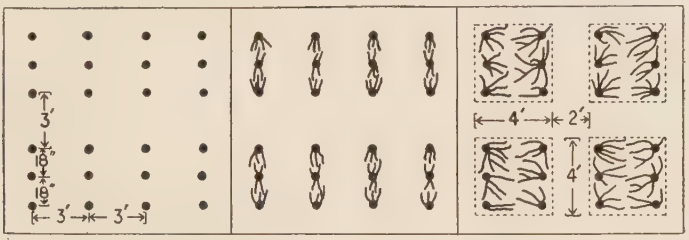


FIG. 2.—Six parent plants in 3 ft. square. Method 4.

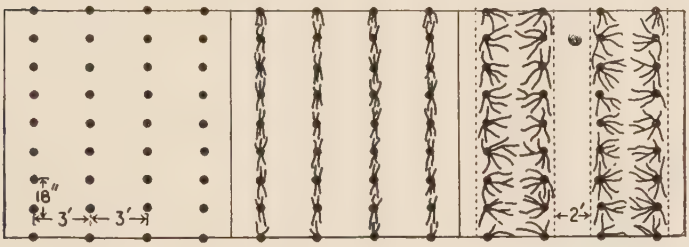


FIG. 3.—Alternate row. Method 5.

TABLE I.

RUNNER YIELDS AND GRADES GIVEN BY VARIOUS ISOLATED BLOCK METHODS AND ALTERNATE ROWS.

| Method. | Number of parent plants per acre. | Runner yield, 1,000's per acre. | | | Runners per parent plant. | | |
|---|---|---|---|---|---|---|---|
| | | 1st grade. | 2nd grade. | Total. | 1st grade. | 2nd grade. | Total. |
| Four parent plants in 3 ft. square: runners not limited (Fig. 1) .. .. .. .. | 4,840 | 76·4 | 154·4 | 230·8 | 15·8 | 32·2 | 48·0 |
| Four parent plants in 3 ft. square: runners limited .. | 4,840 | 75·4 | 13·4 | 88·8 | 15·6 | 2·8 | 18·4 |
| Four parent plants 3 ft. 6 in. × 3 ft., with 2 ft. 6 in. to next block. Rows 3 ft. apart. Runners not limited .. .. | 4,840 | 58·7 | 169·2 | 227·9 | 12·1 | 35·0 | 47·1 |
| Six parent plants, in block 3 ft. × 3 ft. Runners not limited (Fig. 2) .. .. | 7,260 | 76·7 | 207·0 | 283·7 | 10·6 | 28·5 | 39·1 |
| Alternate row: parents at 18 in. in rows 3 ft. apart. Runners not limited (Fig. 3) .. | 9,680 | 89·2 | 275·4 | 364·6 | 5·3 | 16·2 | 21·5 |

**Experiment II.** In this trial the square block with parents at the corners, which by then had become the standard practice for isolated block propagation, was compared with " cartwheel " methods in which the parent plants were in the centre of the block, in the hope that as the runners grew naturally outwards they could to some extent be swept into blocks by the horse-hoe, so lessening the labour of hand laying (Figs. 4 and 5). The plants were planted as a commercial runner bed of about 1¼ acres

FIGS. 4-5.—Runner arrangement in Trial II.

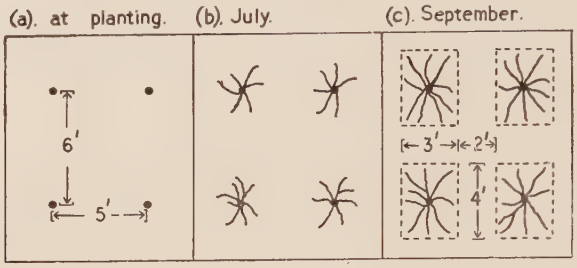


FIG. 4.—Parents in centre of 6 ft. × 5 ft. rectangle. One parent per block (Trial II, Method 1).

FIG. 5.—Parents in centre of 6 ft. × 5 ft. rectangle. Three parents per block (Tria II, Method 3). Method 2 was similar, but with two parents per block.

in extent. Each treatment occurred in randomized strips in three large blocks, so that commercial cultivation conditions would be experienced. The plants were Royal Sovereign M.35, planted in October, 1938. The runners were lifted in April, 1940. Once again 2 grades were made, but as these plants were lifted in spring, Grade 1 comprised plants with leaves over 2½ in. and good crowns, and Grade 2, plants down to about 2 in., but of plantable quality.

The results are given in Table II.

TABLE II.

RUNNER YIELDS AND GRADES GIVEN BY ISOLATED BLOCKS WITH PARENTS IN CENTRE (CARTWHEEL METHOD) AND AT CORNERS (SQUARE METHOD), 1939.

| Method. | Number of parent plants per acre. | Runner yield, 1000's per acre. | | | Runners per parent plant. | | |
|---|---|---|---|---|---|---|---|
| | | 1st grade. | 2nd grade. | Total. | 1st grade. | 2nd grade. | Total. |
| 1. " Cartwheel." Parents in centre of 6 ft. ×5 ft. rectangle. 1 parent per block (Fig. 4) .. | 1,452 | 32 | 33 | 65 | 22·0 | 22·7 | 44·7 |
| 2. Ditto. 2 parents per block .. | 2,904 | 73 | 66 | 139 | 25·1 | 22·7 | 47·8 |
| 3. Ditto, 3 parents per block (Fig. 5) .. .. .. .. | 4,356 | 89 | 65 | 154 | 20·4 | 14·9 | 35·3 |
| 4. 3 ft. × 3 ft. square block with parents at corners (Fig. 1) .. | 4,840 | 115 | 80 | 195 | 24·0 | 16·5 | 40·5 |

It is seen that, under these commercial conditions, the yields were less than those in Experiment I. Normally a greater yield of rooted runners is obtainable by lifting in spring rather than in autumn, and the difference between 230 thousand plants from plants at 3 ft. square in Experiment I, and 195 thousand in Experiment II (when an increase might have been expected) is an indication of the less

reful attention that individual runner laying can receive, under commercial conditions. The latter ure was good for a commercial runner bed. The new " cartwheel " methods all gave smaller yields r acre and the methods with fewest plants gave the smallest yields, their total yields and those of st grade plants all differing significantly from each other. The arrangement of 3 parent plants gether in the centre of the block gave the yield nearest to that of the square blocks, but even with the eoretically greater area per plant, the yield of plants per parent was smaller. Thus it seems likely at the parents in the " cartwheel " blocks were suffering greater competition from each other and om their runners than those in the " square " blocks. As none of the " cartwheel " methods had ite the same number of parent plants per acre as the square method, however, it was decided to make nother comparison in Experiment III.

**Experiment III.** This was carried out with the new and more vigorous Royal Sovereign M.40 one, and compared " square " blocks, spaced at 4 ft., with " cartwheel " blocks with 4 plants or plants grouped in the centre of an 8 ft. square (Figs. 6-8).

FIGS. 6-8.—**Runner** arrangement in Trial III.

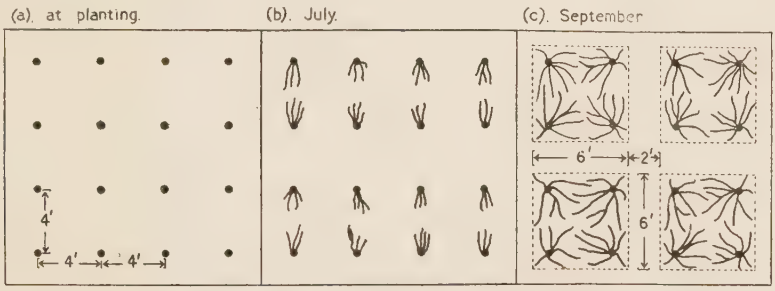


FIG. 6.—Four parent plants in 4 ft. square (Trial III, Method 1).

FIG. 7.—Three parent plants in centre of 8 ft. square (Trial III, Method 2).

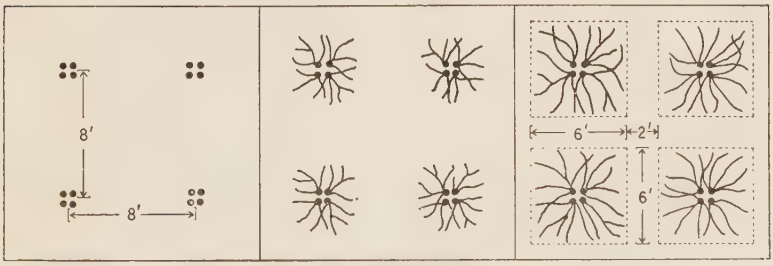


FIG. 8.—Four parent plants in centre of 8 ft. square (Trial III, Method 3).

The plants formed a 1-acre runner bed and were planted in November, 1939. The runners were fted in October, 1940, the standards being approximately as for Experiment I ; the results are given n Table III.

It can be seen that, with these vigorous plants, even at the relatively wide spacing of 4 ft. a yield f 186 thousand plants per acre (an excellent yield for autumn plants) was obtained. The cartwheel nethod, even with the same number of plants per acre, gave a smaller yield and a smaller proportion f first to second grade plants. Thus this method is not so satisfactory in yield. There does seem o be some saving in labour, but not so much as was expected. Roguing is also less easy, with the

parents surrounded by a mass of plants. On the whole it seems desirable to keep the parent plant accessible for cultivation, at least on one side, for as long as possible. It is also desirable for good inspection.

The actual yield figures should be interpreted with caution. Yields vary greatly from locality to locality, and from season to season. The figures given are, on the whole, high for Royal Sovereign : but, under good conditions 100,000 plants per acre should not be an unusual yield.

**Discussion.**

*General Considerations.* The foregoing data confirm that, within limits, the closer the spacing of the parents, the greater the runner yield *per acre*, and the wider the spacing of the parents, the greater the yield *per plant*. Thus, where parent plants are not scarce, it is reasonable to plant them closely enough to ensure the maximum yield of plants of suitable quality. If planted too closely, however, there is a risk that overcrowding of runners may occur, leading to poor rooting and etiolation (drawing up) of the leaves. The former is more important than the latter, for long leaf stalks do not necessarily hinder good establishment of a runner (Rogers, 1931), and a careful research study has shown that small plants, above a certain minimum size, are not any less desirable for commercial planting than larger ones (Rogers, 1938). Nevertheless, if plants are badly overcrowded many unmarketable plants are wasted.

TABLE III.

RUNNER YIELDS GIVEN BY "SQUARE" AND "CARTWHEEL" METHODS, 1940.

| Method. | Number of parent plants per acre. | Runner yields, 1,000's per acre. | | | Runners per parent plant. | | |
|---|---|---|---|---|---|---|---|
| | | 1st grade. | 2nd grade. | Total. | 1st grade. | 2nd grade. | Total. |
| 1. "Cartwheel." Three parent plants, in centre of 8-ft. square (Fig. 7) .. .. .. .. | 2,041 | 51 | 69 | 120 | 25 | 34 | 59 |
| 2. "Cartwheel." Four parent plants, in centre of 8-ft. square (Fig. 8) .. .. .. .. | 2,722 | 58 | 84 | 142 | 21 | 31 | 52 |
| 3. "Square." Four parent plants, at corners of 4-ft. square with 4-ft. alleys (Fig. 6) .. | 2,722 | 89 | 97 | 186 | 33 | 35 | 68 |

It follows also that the area of bare ground should be kept to the minimum needed to isolate the blocks. It is a matter of simple arithmetic that, if the isolation alley is of a fixed minimum width, the larger the runner block, the lower the proportion of bare soil. The blocks must be of reasonably small size, however, so that not too large an area has to be grubbed if an infected plant is found, and also so that each plant can be seen from the pathway. The parent plants especially must be readily accessible for inspection. Also the block must allow access for nicotine fumigation apparatus.

For mechanical cultivation and for suitable isolation the clear alleyway at the end of the season cannot normally be less than 2 ft.

With the original 3 ft. square planting the runners can be laid round the outside of the block as well as in the middle, leaving only a 2 ft. alley. This point, although suggested in the technical description (Rogers and Buttfield, 1944), is not always appreciated. Thus, out of a total area of 36 sq. ft., comprised by the block and adjoining half-alleys, the plants occupy 16 sq. ft. or 44 per cent. (Fig. 1). With a 4 ft. square planting, again allowing the runners to spread to leave only a 2 ft. alley, the plants can occupy 36 sq. ft. out of 64, or 56 per cent. of the ground (Fig. 6). This compares favourably with the old "alternate alley" method.

One simple modification of the square system is to run two adjoining squares together, making rectangles containing six plants (Fig. 9). This gives a possible runner-laying area of 52 per cent. with a 3 ft. spacing, or 62 per cent. with 4 ft. spacing of the parents. This modification has been used with success on some special stock nurseries. It will be noted that it is different from the six-plant square blocks.

Another modification, tried on another special stock nursery, is to plant at 4 ft. square, but to lay the runners into long narrow blocks as shown in Fig. 10. The object was to allow more mechanical cultivation and to lessen hand laying. In this system the plants finally occupy 44 per cent. of the

round, and therefore are worse off for space than in a 4 ft. square block. This is borne out in the rower's report that this layout provided many plants too small to sell. The 6-plant double square nentioned above (Fig. 9) would doubtless have been better.

Another arrangement, devised by Mr. Arthur Amos, of Wye, is shown in Fig. 11. This method, sing 4,840 parent plants per acre, provides for lifting the early runners for autumn sale and later nes separately for spring sale. The parents are planted at the spacing shown and the early runners aid in 4 ft. × 2 ft. blocks between them. Later runners are laid outside. In autumn the centre locks are cleared, as shown in Fig. 11 (d), leaving the rest for spring lifting. This is a good device to essen the wastage of plants normally inherent in autumn lifting. It is more difficult to mark out han the square and leaves rather too narrow a space lengthwise between the blocks, since, when the arent plants are fully grown, there is less than 2 ft. between them. This could easily be altered,

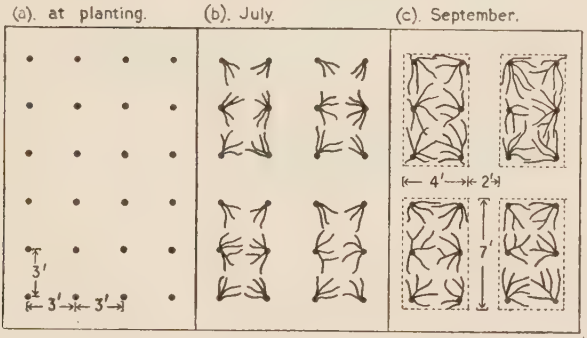


FIG. 9.—The double square, a recommended method of increasing the area utilized by runners. The spacing can be increased to 4 ft. if desired.

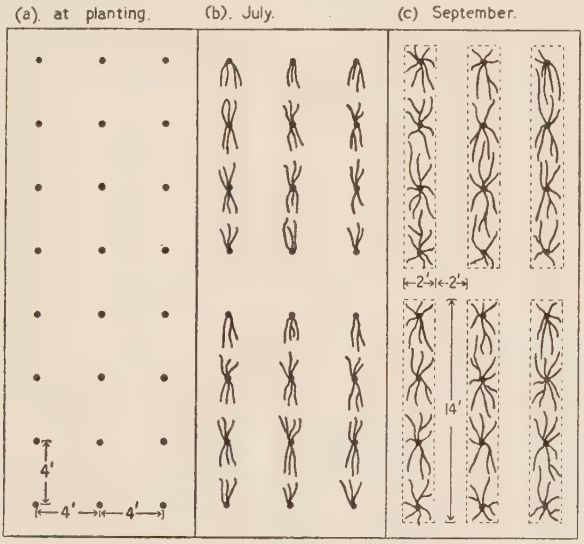


FIG. 10.—Long narrow blocks, not recommended.

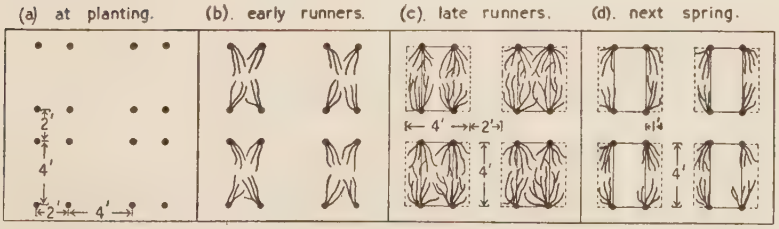


FIG. 11.—Mr. A. Amos's method of laying early and later runners separately, for separate autumn and spring lifting. (d) represents the appearance of blocks after the autumn lifting.

however. As it stands, the plants occupy only about 44 per cent. of the ground. If it were changed to rows alternately 3 ft. and 5 ft. apart, with plants at 4 ft. in the row (Fig. 12), the same system could occupy 56 per cent. of the ground. The number of parent plants at 4 per block would be reduced to 2,722, or if 6 plants were put in the 3 ft. × 4 ft. rectangle, 4,083 would be accommodated. This plan is probably worth trial.

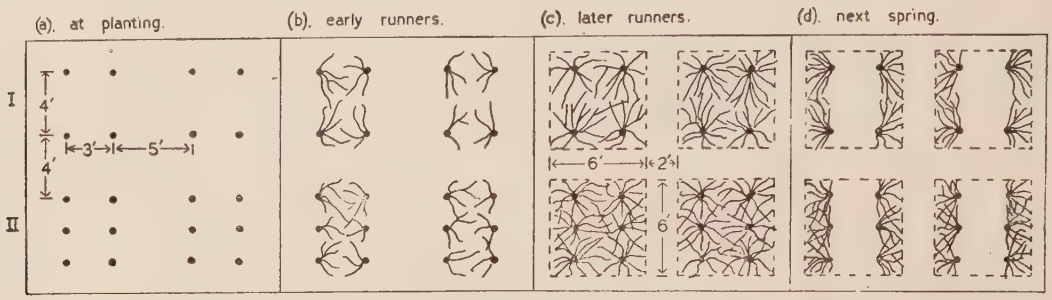


FIG. 12.—Modified method for separate lifting of early and later runners in autumn and spring, utilizing more ground area than in Fig. 11.
I, using four parent plants to a block. II, using six parent plants to a block.

It is clear that many different layouts could be devised, which would still satisfy the Special Stock requirements that the runners from not more than six parents shall be isolated in blocks.

It is sometimes asked if it would not be sufficient to allow the runners to mat all over the field ; and to clear a space around any centre of infection that was found. The answer is that it is not advisable, for it makes really effective inspection and roguing practically impossible. Only if a 100 per cent. virus-free clone were planted in an area where no re-infection could possibly occur would it be safe, and unfortunately such conditions of complete freedom from re-infection have never yet been found. There is often also a residuum of infected plants in the most carefully rogued beds, once a clone has been in circulation for some years. It is certainly worth while to continue the search for simpler techniques and better disease-control measures ; but the troubles are of such a nature that the most careful precautions, such as have proved successful in the Special Stocks Scheme, are still necessary.

**Acknowledgements.**

The author acknowledges with thanks the assistance of Mr. D. Hammond and Mr. R. J. Garner in the field work, and of Miss E. M. Glenn and Miss I. Modlibowska in recording the results and preparing the diagrams.

**Summary and Recommendations.**

1. Three experiments comparing various designs and spacings of isolated blocks for strawberry propagation are described.

2. It is shown that, within limits, the closer the spacing of parent plants, the greater the runner yield per acre, but the smaller the yield per parent. Thus for scarce stocks wide spacing is desirable, but for plentiful stocks closer spacing is worth while to ensure a good yield per acre. Spacing should also be adjusted to suit variety, soil and climate, so that the blocks become full but not overcrowded.

3. Square or double-square blocks give a good compromise between the desirable factors of ease of access, efficient use of ground, and minimizing of hand labour. For most purposes, double blocks comprising 6 plants are now recommended, since this layout increases the percentage of ground occupied by the runners. Similarly, laying the later runners outside the parent plants to leave a minimum cultivated strip of 2 ft. wide is advocated.

Suitable planting distances are 3 ft. × 3 ft. for Royal Sovereign M.40 in dry areas, and 4 ft. × 4 ft. in moist areas. The more vigorous Huxley M.44 commonly needs the wider spacing.

A modified design in which earlier and later runners are laid apart, for separate lifting in autumn and spring respectively is also described.

4. The larger the blocks, the higher the percentage of soil utilized for runner laying ; but blocks must not be too large on account of the need for ready access for close inspection, and for economical roguing. The maximum size of block at present recommended is 10 ft. × 6 ft. Long narrow blocks are wasteful of isolation space.

5. Arrangements in which the parents are in the middle of the block appear to cause unsatisctory competition between runners and parent, and are not easy to inspect. The parent plants ould not be more than about 1 ft. from the side of the block.

6. For the maintenance of strawberry stocks in the highest degree of health and virus-freedom, nditions such as those prescribed for the Special Stock Certificate are necessary. The isolated block ying of runners, to permit effective inspection and roguing, is an important part of this system.

## References.


ARRIS, R. V. (1937). "Virus diseases in relation to strawberry cultivation in Great Britain. *Rep. E. Malling Res. Sta. for 1936*, 201-11.

ASSEE, A. M. (1935). "On the transmission of the strawberry virus Yellow-edge disease by the Strawberry Aphis." *J. Pomol.*, **13**, 39-52.

OGERS, W. S. (1931). "Strawberry Cultivation; strain, time of planting and de-blossoming. *Rep. E. Malling Res. Sta. for 1928-30*, 52-64.

—— (1938). "Strawberry Cultivation Studies. I." *J. Pomol.*, **16**, 63-90.

—— and BUTTFIELD, J. M. (1944). "The Production of healthy Strawberry Runners." *Rep. E. Malling Res. Sta. for 1943*, 87-93.

——, KING, M. E., and MASSEE, A. M. (1939). "Results of Researches in Strawberry Culture." *Rep. E. Malling Res. Sta. for 1938*, 223-34.

# WEATHER CONDITIONS DURING 1946

By H. M. TYDEMAN and A. P. PRESTON

The year 1946 will long be remembered as one of consistently bad weather. It is scarcely possible to recall a single week of uninterruptedly sunny and warm conditions throughout the whole of the summer, while May and August, with about twice the average amount of rain and considerably less than the average quantity of sunshine, provided outstanding examples of unseasonable weather. Although June and July had fairly high totals of sunshine and much about the average rainfall, they were by no means ideal. Rain was recorded on 20 occasions during June and much of it fell during thundery outbreaks in the daytime. July provided one short period of continuously sunny, hot weather, but it was interrupted by showers within a week.

As recorded in the Farm Report, the weather could scarcely have been worse for arable crops and indeed all sections of the farm suffered, weather during harvesting being particularly bad with intermittent rain and cool cloudy conditions. However, despite dull weather with cold NE. or E. winds during April and May, no damaging frosts were recorded during the blossoming season and, where trees were not in an " off " season, moderately good crops of most fruits were obtained.

Generally speaking, temperatures were a little below the average during the greater part of the year and more particularly during the early summer. Rain was very abundant, the year's total of 32·43 inches being 6 inches in excess of the 30 years' average here, and almost 10 inches more than the total rain recorded here during 1945. This total does not represent the highest annual rainfall recorded at East Malling ; the wettest year, since observations commenced in August, 1914, being 1927, in which year 37·34 inches were recorded. February, April, May, August, September and November all had a total rainfall much in excess of normal. Sunshine, on the other hand, was average in amount. The year's total of 1,570 hours was 92 hours more than the 30 years' mean here, the two outstandingly sunny months being April and July. Ground frosts were few and late in the autumn, the first was recorded during the last week in October.

The writers wish to express their thanks to Mr. T. N. Hoblyn for the accompanying diagram (see p. 76), and to members of the Statistical Section for assistance during the year.

SUMMARY OF METEOROLOGICAL OBSERVATIONS DURING 1946.

| Month. | Temperature in Screen. | | | | | No. of Ground Frosts. | Rainfall. | | | Sunshine. | | | Soil Temperatures. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean Maximum. | Mean Minimum. | Highest. | Lowest. | Mean. | | Total in inches. | Heaviest fall in a day. | 30 years' average. | Total Hours. | Average per day. | 30 years' average. | 4 inches. | 8 inches. | 2 feet. |
| January | 42 | 31 | 55 | 17 | 36 | 22 | 1·65 | 0·48 | 2·53 | 67·1 | 2·2 | 45·8 | 34·7 | 36·5 | 39·2 |
| February | 48 | 38 | 55 | 17 | 43 | 8 | 2·69 | 0·70 | 1·82 | 60·0 | 2·1 | 67·3 | 40·5 | 41·1 | 42·4 |
| March .. | 48 | 34 | 60 | 25 | 41 | 16 | 1·82 | 0·37 | 1·52 | 85·0 | 2·7 | 118·7 | 39·1 | 39·0 | 40·8 |
| April .. | 60 | 38 | 75 | 26 | 49 | 15 | 3·06 | 1·06 | 1·99 | 194·4 | 6·5 | 131·7 | 49·2 | 47·6 | 49·3 |
| May .. | 58 | 43 | 69 | 30 | 50 | 2 | 2·92 | 0·97 | 1·77 | 192·8 | 6·2 | 198·3 | 53·4 | 51·0 | 52·1 |
| June .. | 65 | 48 | 75 | 39 | 56 | 0 | 1·68 | 0·28 | 1·44 | 212·7 | 7·1 | 204·0 | 60·4 | 57·4 | 57·4 |
| July .. | 72 | 52 | 83 | 42 | 62 | 0 | 1·95 | 0·68 | 2·20 | 269·3 | 8·7 | 190·7 | 64·9 | 62·9 | 63·6 |
| August .. | 68 | 51 | 83 | 42 | 59 | 0 | 5·03 | 1·41 | 2·27 | 175·5 | 5·7 | 181·9 | 61·7 | 60·2 | 61·9 |
| September | 65 | 50 | 74 | 43 | 57 | 0 | 2·62 | 0·43 | 2·08 | 126·5 | 4·2 | 145·8 | 57·2 | 56·6 | 58·2 |
| October | 57 | 43 | 69 | 25 | 50 | 3 | 1·84 | 0·94 | 2·82 | 92·8 | 3·0 | 100·9 | 50·8 | 51·0 | 54·7 |
| November | 52 | 41 | 63 | 30 | 46 | 2 | 4·88 | 0·95 | 3·15 | 46·0 | 1·5 | 53·7 | 44·9 | 45·3 | 47·8 |
| December | 42 | 31 | 51 | 16 | 36 | 22 | 2·29 | 0·64 | 2·65 | 47·6 | 1·5 | 39·1 | 35·4 | 36·7 | 40·9 |
| Totals | | | | | | 90 | 32·43 | | 26·24 | 1569·7 | | 1477·9 | | | |

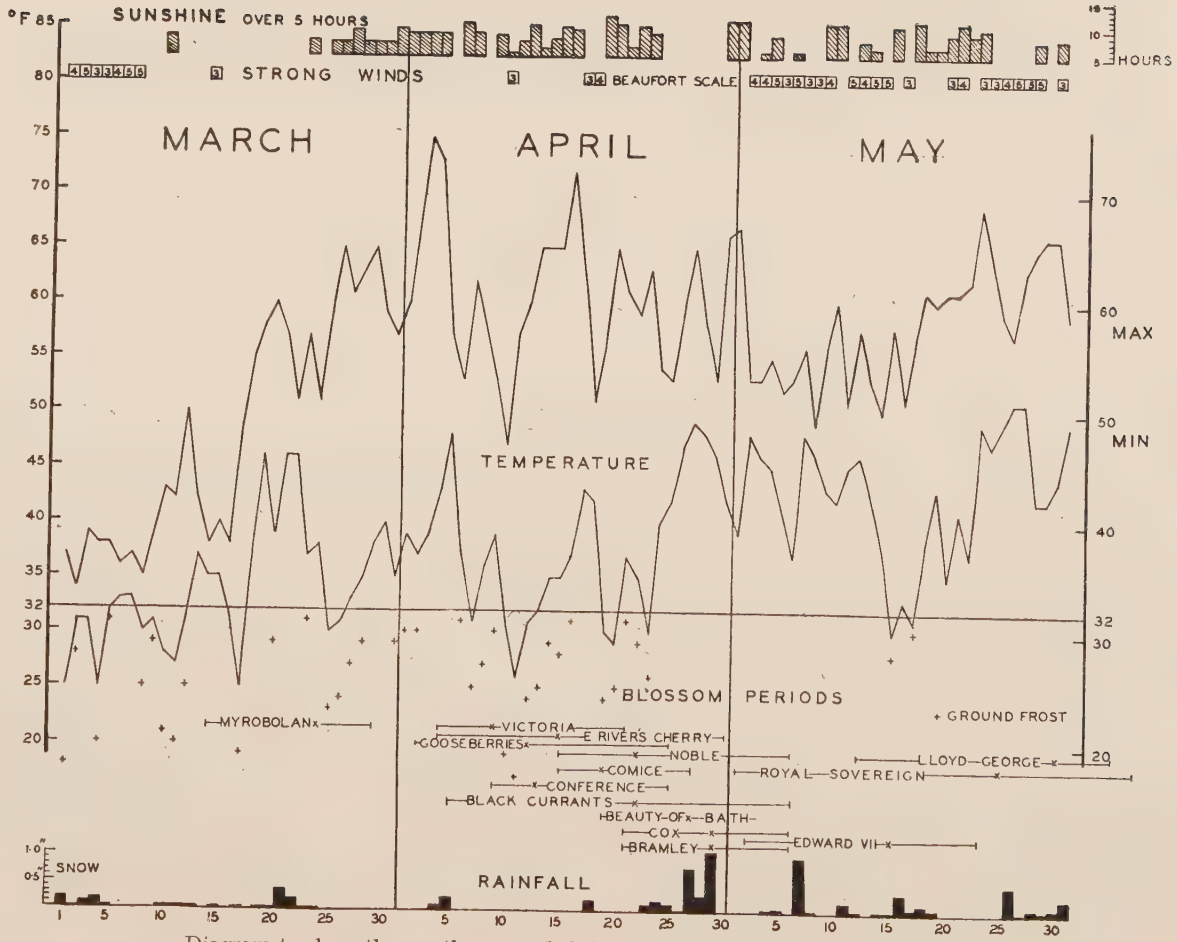


Diagram to show the weather recorded during the Blossoming Season of 1946.

## STATISTICS

# THE MEASUREMENT OF FRUIT CROPS BY SAMPLING

By S. C. PEARCE

### Introduction.

From the earliest days at East Malling copious records have been made of tree growth and behaviour, crop measurements being of prime importance. Records have usually been made of the number of fruits and their weight and sometimes of the colour of each individual fruit. In 1939, however, the Second World War brought about a sharp reduction in the labour that could be allotted to the task and less laborious methods of recording became urgently necessary.

Plainly there were only two possibilities, either to reduce the number of measurements or to find quicker methods. To some extent both courses were adopted, but in respect of crop measurements the solution was mainly found by devising sampling methods. These have been so successful that it has been possible to take more measurements rather than fewer despite the stringency of the labour shortage. In describing these methods it is hoped that they will prove of value at other research stations, though modifications may well be called for. The two factors most likely to necessitate changes are : (1) Overseas trees are frequently larger than British ones and so carry larger crops. This may affect the methods to be described for determining fruit size, but it is unlikely to affect those for crop weight or fruit colour. (2) The use of different containers, which will be discussed at the end. In any event, the procedures here to be described are not given as rigid and immutable rules, but as means by which the various problems may be approached and they should be applied according to the judgement of the worker concerned. No attempt will be made here to justify the methods recommended, but all have been examined critically from a statistical standpoint (Pearce, 1943, 1944, deals with some of these methods).

An objection that is sometimes made against sampling methods is their alleged lack of accuracy. It should be remembered, however, that in any field trial a whole class of trees is judged on the basis of a few ; and a further sampling process can do no harm provided the additional variation it introduces is lost in that already present. This standard of accuracy is a high one, but it has been sought throughout this work. Where it has not been attained, the fact will be stated.

### General Organization for Sampling Methods.

**Equipment and Personnel.** To use these methods a supply of standardized containers is essential, and all boxes not exactly of standard size or weight must be discarded. Little else is needed beyond weighing apparatus and writing materials, and also chalk for marking the boxes to avoid confusion between them.

As to personnel, all recording is a job for the conscientious, and this is especially true of sampling methods. For example, the weighing of a sample calls for more care than the weighing of the boxes of an entire crop, because the same error can be more serious. The attitude " that it is only a sample " must be continually guarded against.

**Preliminary Organization.** Crop measurement is done much more easily if all the fruit is picked at one time, and the co-operation of the farm staff should be sought to avoid more pickings than are necessary. In recording a picking it is advisable to proceed always in the order (1) crop weight, (2) fruit size and (3) fruit colour. While a measurement can sometimes be made to serve two purposes, this is rarely worth while and usually only makes things more complicated for the recorders. For the same reason, it is usually better, when several characteristics are to be measured, to use a different team for each.

The time to be allowed for each operation needs careful consideration. Since accuracy is the first essential, recorders should not be unreasonably hurried, so the estimates here given are fairly generous. In addition, time must be allowed for recorders to collect their apparatus, to go to the orchard indicated and to return, operations that are often very wasteful of time.

**Instructions to pickers.** Complicated instructions to pickers usually defeat their own end, but two rules only need be insisted upon : (1) Each box or basket must be *filled* before another is started. (2) Boxes must be stacked in threes in the order in which they are filled. Baskets should be laid

out in some way that will enable recorders to know the order of filling. It is simplest for everyone if these rules are made part of the general farm routine and are observed even when no sampling is intended.

**Instructions to recorders.** It is upon the recorders that the chief burden of sampling necessarily falls and time spent in their instruction is rarely wasted. They should be fully conversant with the following points :—

Where a method requires that a sample be taken " from the top of a container ", this means as a horizontal layer, care being taken that the last fruits selected are those that protrude most above the general level.

Taking a sample from " the corner of a box " means as a vertical section to the bottom, and calls for careful handling. One hand should be used to hold back the resulting wall of fruits, while the other is used to remove fruits singly, taking care not to bring about the collapse of the wall. When the sample has been removed, it should be possible to look down the resulting hole with its vertical sides like looking down a well. Sometimes the last fruits are difficult to remove, and it is then permissible to grasp those needed and to pull, but this should not be done except of necessity. Some skill is needed, incidentally, to gauge how large a hole to make to secure a given number of fruits.

A constant difficulty is the rejection or acceptance of distorted or under-sized fruits. Recorders should include in a sample all fruits that are perfectly formed or that would be so but for disease, and should reject none solely on the grounds of size.

If a recorder finds that a box from which a sample is to be taken is not completely filled, he should not fill it with fruit from another source. This mistake has often been made.

Finally, before removing the fruit from the orchard, it is advisable to look through the records and to check any figures that seem incorrect.

## The Estimation of Crop Weights.

**Methods of Computing.** The methods all reduce to counting the containers, and multiplying by the weight of fruit in a container as estimated by sampling. In the past, four methods have been considered. Of these, the so-called " Optimum Method " gives very good accuracy at the expense of a great deal of computing and is of value only as a yard-stick for the other three, which are as follows :

*First Method* : Averaging all boxes that have been weighed in the experiment and, for each tree, multiplying the number of boxes by this average.

*Second Method* : Using the actual weights for all boxes that have been weighed and the general average for those that have not.

*Third Method* : Taking the mean weight of each tree's sample boxes and multiplying by the number of boxes.

The contents of the last box are usually estimated to the nearest quarter of a full box by measuring the depth of container unfilled. Unless otherwise stated, this procedure is sufficient.

**Techniques of Sampling.** For each kind of fruit two techniques will be given.

Technique *A* can be used for all purposes, but Technique B is inadequate if the treatments are likely to affect the density of fruit or if it is proposed to examine the results by an analysis of variance. For comparison of varieties *A* must always be used, and it is also recommended if there are twelve or fewer trees.

After weighing, the boxes should be replaced in case any samples for fruit size are to be taken.

*Apples, Technique A.* Two boxes, which in England would each contain about 40 lb. of fruit, are weighed from each tree, one being taken from the top of a stack and one from the middle of, if possible, a different stack. If two recorders are used they will need about three and a half minutes for each tree. The Method of Computing is the Third.

*Technique B.** One box, taken from the middle of a stack, is weighed from each tree. The two recorders are allowed three minutes per tree. If there are three full boxes or less the Third Method of Computing is used, but otherwise the First.

Slight improvements in accuracy at the expense of more labour may be effected by (i) weighing the contents of the last box if there is only one box full, (ii) using the Second Method of Computing throughout.

* A further technique, *C*, has been used at East Malling in which the general average is determined from some of the trees only. From six to twenty boxes are weighed, each from a different tree, the Method of Computing being of necessity the First. If all the trees in the experiment are giving crops of six boxes or more this technique may validly be substituted for *B*, but otherwise it is not recommended and it has been adopted only on account of extreme shortage of labour.

*Pears.* Errors of estimation with pears appear to be somewhat greater than with apples, but the same methods may be applied without modification. The greater weight of pears in a standard box (about 48 lb.) slows up recording a little.

*Plums.* All work at East Malling on the estimation of crops of plums has been based on the 12-lb. chip-basket as the standard container, and Table I sets out the numbers of baskets that should be taken and the appropriate Method of Computing. The baskets chosen should be distributed through the crop. The content of the last basket needs to be weighed if there is only one full basket, but otherwise it may be estimated to the nearest quarter. In applying the Second Method of computing when varying numbers of containers are weighed from each tree, the general average should be calculated from only one basket per tree.

TABLE I.

DETAILS OF TECHNIQUES RECOMMENDED FOR USE WITH PLUMS.

| Size of Crop in full baskets. | TECHNIQUE A. | | TECHNIQUE B. | |
|---|---|---|---|---|
| | No. of baskets weighed. | Method of computing. | No. of baskets weighed. | Method of computing. |
| 1 | 1 | III | 1 | II |
| 2 or 3 | 2 | III | 2 | II |
| 4 | 3 | III | 2 | II |
| 5-7 | 3 | III | 3 | II |
| 8-10 | 4 | III | 3 | II |
| 11-19 | 4 | III | 4 | III |
| 20 or more | 5 | III | 5 | III |

**The Estimation of Fruit Size.**

By " Fruit Size " is meant the " weight of 100 fruits ". An obvious method of measurement is to divide the crop weight by the number of fruit, the result being proportionately as accurate as the estimate of crop weight used. The quicker methods described below are not quite as accurate, and sometimes the error of estimation will not be negligible compared with the variation already present ; but this will happen only with very uniform plantations.

*Apples.* It is understood that the boxes are stacked in threes. The method is (i) to select a number to represent on the average for all trees approximately the number of fruits in three-quarters of a box, choosing for preference a multiple of 30, (ii) to divide a sample of this size equally between the top boxes of complete stacks taking the fruit evenly from the tops of the boxes and (iii) to weigh the sample correct to 0·1 lb. If the total crop of the tree occupies less than one stack (i.e. 3 boxes) the sample should be taken from the last full box. If there is less than one full box it is best to count and weigh the entire crop.

The sample value, $S$, for the weight of 100 fruits is not always directly applicable to the crop as a whole because of the tendency for the small apples to slip down between the large ones. If $S$ is less than 20·0 lb. no correction is needed ; if it is greater, the quantity, $0{\cdot}891\,S + 2{\cdot}18$, has been shown by regression methods to give a good estimate of the true value for the crop.*

The accuracy with small, smooth fruits is better than with large irregular ones, a fact that will help to decide sample size if there is any real doubt.

There is some evidence that trees with exceptionally large fruits and very small crops sometimes give unreliable sampling results. Until more is known, it would be wise to count and weigh all the fruit of such a tree, when there are less than two boxes of apples and the sample occupies more than one box.

At the end, the sample should be returned to the top boxes in case any colour samples are to be taken. This does not mean, of course, that individual fruits must be returned to the box from which they came.

This method is best carried out by two recorders, who should be allowed three minutes a tree. Since counting apples requires about one second a fruit, the method saves time, except when there are on the average fewer than 250 apples to a tree and the crop weights are already known. It is then quicker to divide each crop weight by the number of fruits.

* Tables have been prepared for sample sizes 90, 120, 150, ———240, and samples weights 20·0, 20·1, 20·2, ———40·0 lb. in which this correction has been applied where necessary. Copies will be sent on request.

*Pears.* Essentially the same method may be used for pears as for apples, except that, under English conditions, it has been necessary to divide the sample between all full boxes, because there is usually no complete stack of three boxes. Also, a sample of rather less than three-quarters of a box may be used, especially when the fruits are small.

With pears, as with apples, there is a tendency for the smaller fruit to slip down and miss the sample, but the effect is not large enough to call for a correction. The time needed is about the same as for apples, except that large crops take rather longer on account of the unstacking and restacking of boxes. With small crops of less than 250 fruits a tree, it is again worth while to count the entire crop if the weight is known, rather than take a size sample.

*Plums.* A method has already been put forward in the following words :

" . . . it is recommended as a general rule that a sample from two to four pounds be taken, divided between at least two containers. It is difficult to suggest a standard procedure, because plums are picked into so many different kinds of boxes, sieves and chip baskets, and give crops of such greatly varying sizes. ' However, it should generally be possible to take a sample of 60 fruits, divided equally between three containers, and to weigh it to the nearest 0·1 lb. When this is not convenient, the general rule will usually suggest an alternative." Samples should be taken evenly from the tops of containers.

By this method there will again be a small bias due to slipping down, which has not been evaluated because the method is not completely standardized. Though not strictly negligible it is unlikely to have any serious consequences.

**Estimation of Fruit Colour for Apples.**

Fruit Colour is an extremely comprehensive term and is here applied solely to the proportion of the surface coloured red. No account is taken of intensity of colour, which is generally measured in categories by reference to colour standards. To measure fruit colour in full each apple is examined and graded thus :—

1. Less than one-quarter coloured. 2. One-quarter or more coloured but less than one half. 3. One-half or more coloured but less than three-quarters. 4. Three-quarters or more coloured. A figure for the whole crop is then obtained by calculating the mean grade. The results arrived at are readily intelligible, but there is a large personal factor. Thus, stripes and flecks can be recorded only by integrating the patches, a matter upon which recorders might well disagree ; while indefinite colour boundaries give rise to similar trouble. Methods must be adjusted to varieties, as for example, with Cox's Orange Pippin, when it is commonly easier to observe absence of green colour than presence of red. No sampling method had been found the error of which is lost in the variation necessarily present, but the course to be described does not fall far short.

It is not, unfortunately, possible to use size samples to estimate colour also, because fruit tends to be distributed in the boxes in layers of about the same colour. It is, therefore, necessary to take the samples as a vertical section through the crop drawing some fruit from each level of each box. While the size of sample must be determined by the variety, the basis of procedure is always to take a number of units of ten apples, each unit being taken vertically from one corner. Table II sets out the numbers of units needed per box. If the variety has a clearly delimited flush in one patch the minimum figure may be used. Most varieties need the middle figure, while a puzzling variety with many patches of doubtfully defined colour needs the maximum. A partly-filled box should yield as many units as the full boxes, but they should be proportionately smaller. The sample having been obtained, the individual fruits should be graded as described and the mean grade calculated. This will give a reasonably good approximation to the mean grade for the whole crop.

TABLE II.

DETAILS OF TECHNIQUES FOR COLOUR GRADING APPLES.

| Number of full boxes. | Number of units needed from each box. | | |
|---|---|---|---|
| | Minimum. | Average. | Maximum. |
| 1 | 4 | 4 | 4 |
| 2 | 2 | 3 | 4 |
| 3 | 2 | 2 | 3 |
| 4 or 5 | 1 | 2 | 2 |
| 6 or 7 | 1 | 1 | 2 |
| 8 or more | 1 | 1 | 1 |

It takes about 25 seconds to draw ten apples from the corner of a box, and about 5 seconds to grade each fruit. Time must also be allowed for unstacking boxes, moving apparatus and so on.

In view of the large personal factor in colour grading it is a good plan to allot one recorder only to each trial. If this is not possible, then each recorder should be allotted an equal number of trees from each treatment, e.g. a certain number of complete blocks in a Randomized Block design or complete rows or columns in a Latin Square, so that personal differences may be eliminated by the experimental design.

**Adaptations of the Methods Described.**

The methods described were evolved in English conditions. Hence weights are in pounds and a " box " means the standard bushel orchard box of English fruitgrowing. The principles, however, should prove valid for other conditions, and it is hoped that the following notes will help in making any adaptations called for.

*Weight of crop.* The box used in this work contains 40-42 lb. (18-19 kilos) of apples and 48-50 lb. (22-23 kilos.) of pears. The chip baskets contain about 12 lb. or 5·5 kilos of plums. With larger containers little modification will be called for, though the use of very large boxes for apples and pears might make it necessary to measure the quantity of fruit in the last box more accurately than in quarter-boxes. With smaller containers (or with a different species) it would be necessary to consider the problem *de novo* using the algebra upon which the methods for estimation of crop weight were based. Particulars will be sent on request, though some have already been published (Pearce, 1944).

*Fruit size.* With different containers it is necessary to ensure only that the sample for apples and pears does not on the average weigh less than 30 lb. or 13·5 kilos., and that stacks of apple boxes do not contain more than 150 lb. or 68 kilos. For plums, the size of container is in any case unspecified. It is probable that the correction for slipping down will depend to some extent upon the container used.

These methods were devised with crops of apples rarely in excess of ten bushels (about 400 lb.) per tree and, of pears, rarely more than four (about 200 lb.) and there is consequently no empirical evidence how the methods would work with larger crops. It is likely that they would prove effective in such circumstances, but it would be as well to test this before making extensive use of them. It would also be worth while to enquire if pears can be sampled in the same way as apples by using only the top boxes of stacks, an enquiry impossible with small crops.

*Fruit Colour.* If very deep containers were used, it might prove impossible to take the samples from the corners of boxes and, since this is essential to the method, no adaptation would be possible. Shallower containers, on the other hand, would make the method easier to apply and would not detract from its accuracy. For easy varieties it is necessary to grade 40 apples, for most 60 and for difficult ones 80 ; and the sample should be distributed evenly as a vertical section through the crop so that no level of fruit is represented more than another. To do this with a large crop it is commonly necessary to take more than the stated number of apples, because there is a practical lower limit to the size of hole that can be made in the corner of a box.

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**Summary.**

A description is given of the methods evolved at the East Malling Research Station for estimating the total weight and fruit size of crops of apples, pears and plums, and fruit colour for apples. Notes are appended on the adaptation of these methods to other conditions.

References.

Edgar, J. L., and de Wet, A. F. (1935). " An experiment in Sampling Technique for Size and Colour of Apples. Bramley's Seedling on Rootstock No. II, 1934 Crop." *Rep. E. Malling Res. Sta. for 1934*, 130-4.

Hoblyn, T. N., and Edgar, J. L. (1938). " Experiments in Sampling Technique. II. Size and Colour of Allington Pippin, 1936 Crop." *Rep. E Malling Res. Sta. for 1937*, 168-72.

(*The above two papers describe some preliminary work at East Malling on the subject of apple sampling.*)

PEARCE, S. C. (1943). "An Investigation into Means of reducing the Labour needed for recording Crops." *Rep. E. Malling Res. Sta. for 1942*, 36-40.

——— (1944). "Sampling Methods for the Measurement of Fruit Crops." *J. roy. statist. Soc.*, **107**, 117-26.

(*The evolution of the methods described in this paper. The first deals only with apples.*)

HOBLYN, T. N. (1931). "Field Experiments in Horticulture." *Imp. Bur. Hort. and Plant. Crops Tech. Commun.*, **2**, 20-5.

ROGERS, W. S. (1931). "Recording apparatus for horticultural experiments including automatic counting devices." *Rep. E. Malling Res. Sta. for 1928, 1929, and 1930.* II. Suppl., 65-73.

(*These describe the measuring apparatus in use at the East Malling Research Station.*)

MCMUNN, R. L. (1941). "An inexpensive home-made Scale for weighing Fruit." *Proc. Amer. Soc. hort. Sci.*, **38**, 205-8.

(*A description of apparatus for weighing individual fruits.*)

WHITE, D. G. (1937). "The size of Apples in Relation to their location on the Tree." *Proc. Amer. Soc. hort. Sci.*, **30**, 132-4.

(*It is shown,* inter alia, *that fruits on the outside of a tree are larger than those inside.*)

LOTT, R. V. (1944). "A spectral Analysis of Colour Change in Flesh and Skin of maturing Grimes Golden and Stayman Winesap Apples." *Proc. Amer. Soc. hort. Sci.*, **44**, 157-71.

(*This is written chiefly from the point of view of gauging ripeness.*)

## PLANT PHYSIOLOGY

# USE OF SPRAYS TO CONTROL FRUIT DROP, ESPECIALLY THAT OF YOUNG FRUIT OF COX'S ORANGE PIPPIN

By M. C. VYVYAN and H. W. B. BARLOW

Experiments in the U.S.A. in 1939 (Gardner *et al.*, 1939) showed that dilute sprays of certain synthetic growth substances sometimes greatly reduced the pre-harvest drop of apples.

Experiments with sprays of these substances were begun in this country at East Malling in 1940, and at Long Ashton in 1941. The East Malling results have been described in a series of brief progress reports (Vyvyan, 1941, 1942, 1943, 1944) and those from 1940 to 1945, inclusive, have been summarized fully in a longer communication (Vyvyan, 1946*a*). The present paper deals with the results obtained in 1946.

Three reports on the results at Long Ashton have also appeared (Berry *et al.*, 1942 ; Swarbrick, 1943 and 1945).

During these years, much work has been published by many authors in several countries, especially the U.S.A., and a rather detailed review covering, as far as possible, all work at home and abroad on the subject has recently been published (Vyvyan, 1946*b*). The results have revealed considerable varietal differences in response to sprays. Promising results were obtained at East Malling in 1940 with the apple varieties Beauty of Bath and Worcester Pearmain with sprays of α-naphthalene-acetic acid (NAA) at the low concentrations of $2\frac{1}{2}$ to 5 parts per million ; a higher concentration, 10 parts per million, gave still better results with Worcester in 1943, with both varieties in 1945, and with Miller's Seedling in 1942. The use of this spray on these three varieties was recommended (Vyvyan 1945) and has become a routine practice at East Malling. Similar sprays have been in commercial use on a large scale in the U.S.A. for several years.

Good control was obtained with a very weak spray on Conference pear in 1942, when picking was postponed, but less was obtained with sprays at 5 parts per million on Cox's Orange Pippin and very little with Bramley's Seedling in 1942, 1943 and 1945.

The reports from Long Ashton showed that Edward VII in 1941 and 1942 and Allington in 1942 failed to give promising results, but trials with Beauty of Bath and Worcester in 1944 fully confirmed, for that locality, the results obtained with those varieties at East Malling.

Similar varietal differences in response have been reported by many workers, and suggest that each variety must be tested individually. It is possible that other substances may be found which will control drop in varieties where NAA has failed. The prospect of such specificity has been enhanced by the recent discovery (Batjer and Marth, 1945) that 2,4-dichloro-phenoxy-acetic acid (DPOA) gives better control than NAA with one apple variety (Winesap), but is ineffective with others. This result was the first considerable success with a substance not closely related to NAA. This substance (DPOA) has already been tried on Cox at East Malling in 1945, but the results were masked by a severe attack of brown rot ; both it and NAA have been tried again on Cox in 1946, with results as reported below. They will be tried on Bramley when trees bearing a suitable crop are available.

The possible effect of anti-drop sprays on the ripening of fruit and its behaviour in storage requires further examination. No effect was found in the case of Bramley at East Malling in 1945 ; and Batjer and Moon (1945) report that mid-season and late apple varieties are apparently unaffected, but that ripening of certain summer varieties is accelerated by sprays of NAA, especially when the spray is applied late and picking is postponed. Similar results were obtained with Williams' Bon Chrétien (Bartlett) pears (Gerhardt *et al.*, 1945).

### Control of July and Pre-Harvest Drop in Cox's Orange Pippin.

This variety, at East Malling, tends to lose a large proportion of its fruit during the month of July, two months or more before they are ready to be picked. Little success in the control of drop of young fruit by early sprays seems to have been reported anywhere as yet, but, in 1940, a small, significant reduction in drop, during the first four weeks after spraying, was obtained in Cox at East Malling by spraying on 24th July with NAA at the low concentration of 5 parts per million. This

suggested that a stronger spray, applied earlier, might give some control of the early drop ; and it was decided to try the effect of applying a spray at 10 parts per million on 1st July—some three months before the picking date. Sprays of NAA, however, often seem to be effective for only three or four weeks and some attempt at controlling the drop during the remaining period seemed desirable. One possible way of achieving such control has been suggested by Batjer and Marth (1945), this consists in using a spray containing both NAA and DPOA, since the latter substance reduces drop in some apple varieties, such as Winesap, during a period of several weeks, starting some three or four weeks after application. Four treatments were therefore tried on Cox in 1946 ; these were : Unsprayed control, DPOA at 10 p.p.m., NAA at 10 p.p.m., and DPOA plus NAA, both at 10 p.p.m.

Two rows of 31 mature trees were used. As the branches of adjacent trees in each row overlapped, units of three trees were used ; each unit was separated from the next by a " buffer " tree not included in the experiment. There were four blocks of trees, each made up of four units—one unit for each treatment. The initial crop varied considerably from tree to tree and had not been thinned ; many trusses on some trees bore two or three fruits. It was estimated at some two to four bushels per tree. The sprays were applied on 1st July at the rate of about 4 gallons per tree. All dropped fruits already under the trees were cleared away on the date of spraying (1st July), and the subsequent drops under each unit of three trees were collected and counted on 4th, 9th and 29th July, 14th August, and on the day of picking, 30th September.

TABLE I.

COX'S ORANGE PIPPIN, 1946.

Accumulated percentage drop of fruits from unsprayed trees and from trees sprayed with 2,4-dichloro-phenoxy-acetic acid alone (DPOA), α-naphthalene-acetic acid alone (NAA) and the two substances together (DPOA+NAA.)

| Treatment. | Percentage drops up to : | | | | | Percentage picked. | | |
|---|---|---|---|---|---|---|---|---|
| | 4th July. | 9th July. | 29th July. | 14th August. | 30th Sept. | 2½ in. and under. | Over 2½ in. | Total fruit. |
| Unsprayed .. .. | 30 | 62 | 82 | 84 | 88 | 1 | 11 | 12 |
| DPOA alone .. | 28 | 57 | 80 | 83 | 86 | 2 | 12 | 14 |
| NAA alone .. .. | 24 | 35 | 49 | 52 | 56 | 17 | 27 | 44 |
| DPOA+NAA .. | 24 | 36 | 48 | 50 | 54 | 17 | 29 | 46 |

Brackets indicate non-significant differences.

The accumulated percentage drops from the trees under each treatment (Table I) show that spraying with NAA resulted in a big reduction in the drop, but DPOA had little, if any, effect. Out of every 100 fruits present on the trees on 1st July, 44 fruits were picked from the trees sprayed with NAA and only 12 fruits from the unsprayed trees. The picked fruits were graded into " large " (over 2½ in.) and " small " (2½ in. and under), and there were many more of the latter on the sprayed than on the unsprayed. Most of these smaller fruits were of marketable size and, even if only the larger fruits are taken into account, the gain from spraying was considerable—27 were picked from the sprayed for every 11 from the unsprayed.

TABLE II.

COX'S ORANGE PIPPIN, 1946.

Daily percentage rates of dropping during successive periods.

| Treatments. | Periods : | | | | |
|---|---|---|---|---|---|
| | 1st July to 4th July. | 4th July to 9th July. | 9th July to 29th July. | 29th July to 14th Aug. | 14th Aug. to 30th Sept. |
| Unsprayed .. .. | 12·3 | 13·3 | 4·0 | 1·3 | 0·7 |
| DPOA alone .. .. | 10·8 | 10·8 | 4·2 | 1·3 | 0·5 |
| NAA alone .. .. | 9·3 | 3·4 | 1·3 | 0·4 | 0·2 |
| DPOA+NAA .. | 9·1 | 3·3 | 1·1 | 0·2 | 0·2 |

Brackets indicate non-significant differences.

The percentage rates of dropping per day, taking into account the progressive diminution in the residual numbers of fruits on the trees, are shown in Table II. The heaviest rate, 12 to 13 per cent, occurred during the first nine days of July ; after this it decreased until it averaged less than 1 per cent. during the last six weeks before picking. There is thus little indication of a serious pre-harvest drop in the true sense of the term. Probably the high rate of drop began in June. The rate of dropping from trees sprayed with NAA, after the first three days, was consistently about one-third of that from the unsprayed trees. Thus the spray was effective not only in July, but also after 14th August, more than six weeks after it was applied. Possibly a spray applied in mid-June might have given better control. The fruits were not only retained on the trees, but grew in size ; the drops in July averaged about sixty to the pound, whereas the picked fruits ranged from about $5\frac{3}{4}$ to $6\frac{3}{4}$ to the pound.

**Barnack Beauty.**

This experiment was planned to provide information on (a) the effect of anti-drop sprays on the behaviour of apples in store, (b) the incidence of drop in this variety and (c) the effect of the spray on this drop. Fifty-two trees were used ; twenty-six were sprayed on 2nd October with α-naphthalene-acetic acid at the concentration of 10 parts per million, at the rate of about three gallons per tree. The average crop at the time of spraying was about $2\frac{1}{2}$ bushels per tree. The remaining twenty-six trees were left unsprayed.

The fruits from (A) nine unsprayed, and (B) nine sprayed trees, were picked immediately after the completion of spraying. Those from another (C) nine unsprayed, and (D) nine sprayed trees, were picked on 9th October, which, incidentally, would have been the " commercial " picking date. Those from the remaining (E) eight unsprayed and (F) eight sprayed trees were picked on 16th October. Random samples of fruit from each of these six (A to F) batches of trees were sent to store at the Ditton Laboratory as soon as possible after they had been picked. Thus samples of sprayed and unsprayed fruit were picked and put in store on three occasions, (a) immediately after spraying, (b) one week after spraying and (c) two weeks after spraying.

Dr. C. West reports that no significant differences in storage behaviour were found between sprayed and unsprayed fruits picked on any one occasion ; this result is similar to that found for Bramley's Seedling apples in 1945-6 (Vyvyan, 1946*a*).

TABLE III.

BARNACK BEAUTY, 1946.

Percentage drops from unsprayed trees and from trees sprayed with α-naphthalene-acetic acid at concentration of 10 parts per million on 2nd October.

| | Number of Trees. | Treatment. | Date of picking. | Percentage drops. | | |
|---|---|---|---|---|---|---|
| | | | | up to* 2nd Oct. | from 2nd to 9th Oct. | from 2nd to 16th Oct. |
| A | 9 | Unsprayed | 2nd Oct. | 8·5 | — | — |
| B | 9 | Sprayed | ,, ,, | 9·7 | — | — |
| C | 9 | Unsprayed | 9th Oct. | 9·3 | 4·0 | — |
| D | 9 | Sprayed | ,, ,, | 5·6 | 2·5 | — |
| E | 8 | Unsprayed | 16th Oct. | 7·1 | 2·9 | 5·9 |
| F | 8 | Sprayed | ,, ,, | 6·7 | 1·4 | 2·3 |

* Drops before date of spraying.

The drops under each tree before spraying were collected and removed. Subsequent drops were collected and counted on 9th October (C to F) and 16th October (E and F). The total weight of fruit picked from each tree was determined and the number of fruits per tree estimated by counting the number in a weighed sample. The initial number of fruits on each tree was estimated by summing the number of drops and the estimated number of picked fruits. The percentage drops during each period were calculated from these values and are shown in Table III. Little drop occurred from either sprayed or unsprayed trees even when picking was postponed for a week.

**Trial with Worcester Pearmain, Picked Late.**

Most Plots of Worcester on the Station were sprayed with a proprietary anti-drop spray in 1946, as a routine measure. On one Plot, however, alternate rows were left unsprayed to give a measure of the effect, since this is said to vary considerably with the season. The same Plot had been used for similar trials in 1943 and 1945, but the treatments were arranged so as to avoid any danger of the 1946 results being influenced by after-effects of the earlier treatments.

The spray was applied on 26th August and a second application was made on the same trees on 9th September. Picking would normally have been completed by this date, but was postponed until 18th September.

TABLE IV.

WORCESTER PEARMAIN, 1946.

Accumulated percentage drops from unsprayed trees and from trees sprayed with a proprietary spray at standard strength on 26th August. Normal picking period was the first week in September. Picking was postponed until 18th September.

| | Percentage drops up to: | | | | Percentage picked. | Estimated crop (bushels per acre). | |
|---|---|---|---|---|---|---|---|
| | 26th Aug.* | 3rd Sept. | 9th Sept. | 18th Sept. | 18th Sept. | 9th Sept. | 18th Sept. |
| Unsprayed .. | 3 | 14 | 56 | 91 | 9 | 326 | 69 |
| Sprayed .. | 3 | 11 | 35 | 50 | 50 | 489 | 378 |
| Gain .. .. | — | 3 | 21 | 41 | 41 | 163 | 309 |

*Drops before spraying.

The accumulated drops from sprayed and unsprayed trees are shown in Table IV, where they are expressed as percentages of the crop present on 26th August; this was about $6\frac{3}{4}$ bushels per tree. The spray had little effect up to 3rd September, possibly owing to a spell of cold, wet weather occurring at that time. By 9th September the effect was marked and on 18th September the sprayed trees still bore 50 per cent. of their fruit, the unsprayed only 9 per cent. The fruit were in excellent condition on this date and of very good colour. The results suggest, therefore, that an anti-drop spray is of value for this variety, even in an exceptionally wet season.

**Effect of Sprays on Size of Crops in Following Season.**

It is known that the number of blossoms borne on an apple tree is influenced by the conditions during the previous season, when the blossom buds were formed. Heavy blossoming and, to a lesser extent, heavy cropping tend to reduce the formation of blossom for the following season. Removal of the blossom and early thinning of young fruits tend to promote blossom bud formation. It is desirable to know, therefore, if there is any danger of blossom bud formation being reduced by preventing fruit drop or by any other effect of anti-drop sprays. Some evidence on this problem was obtained in 1946 from trees of Beauty of Bath and of Worcester Pearmain, which had been used in the experiments in 1945. The total crops (picked fruit and drops) on each tree in the two seasons 1945 and 1946 were compared and no effect of the 1945 spray on the 1946 crop was found.

**Acknowledgement.**

The authors wish to express their gratitude to Dr. C. West for his collaboration in the experiment on the storage behaviour of sprayed fruit.

**Summary.**

1. The heavy drop of young fruits in July, common in Cox's Orange Pippin, was largely controlled by a spray of α-naphthalene-acetic acid applied on 1st July; the effect of the spray persisted for three months and the crop was increased two- to three-fold. Sprays of 2,4-dichloro-phenoxy-acetic acid had no effect on drop.

2. A spray of α-naphthalene-acetic acid had no effect on keeping quality of Barnack Beauty apples stored at Ditton Laboratory. Neither sprayed nor unsprayed trees of this variety showed much drop, even when picking was postponed for a week.

3. Good control of pre-harvest drop has again been obtained in Worcester Pearmain with a spray of the same substance.

4. Control of drop in 1945 in Worcester and Beauty of Bath had no effect on the crop borne in 1946.

## References.


Batjer, L. P., and Marth, P. C. (1945). "New materials for delaying fruit abscission in apples." *Science*, **101**, 363.

———, and Moon, H. H. (1945). "Effect of naphthalene-acetic acid spray on maturity of apples." *Proc. Amer. Soc. hort. Sci.*, **46**, 113-7.

Berry, W. E., and Swarbrick, T. (1942). "The influence of alpha-naphthalene-acetic acid sprays on the pre-harvest drop of apples under different systems of pruning." *Rep. Long Ashton Agric. and Hort. Res. Sta. for 1941*, 19-22.

Gardner, F. E., Marth, P. C., and Batjer, L. P. (1939). "Spraying with growth substances to prevent apple fruit falling." *Science*, **90**, 208-9.

Gerhardt, F., and Allmendinger, D. F. (1945). "The influence of naphthalene-acetic acid spray on the maturity and storage physiology of apples, pears and sweet cherries." *Proc. Amer. Soc. hort. Sci.*, **46**, 118.

Swarbrick, T. (1943). "The influence of certain sprays on the pre-harvest drop of apples." *Progress Report II. Rep. Long Ashton Agric. and Hort. Res. Sta. for 1942*, 29-31.

——— (1945). "The prevention of fruit drop in apples." *Rep. Long Ashton Agric. and Hort. Res. Sta. for 1944*, 30-6.

Vyvyan, M. C. (1941). "Reduction of the pre-harvest drop in apples by spraying with a growth substance." *Rep. E. Malling Res. Sta. for 1940*, 46-9.

——— (1942). "Further note on the reduction of pre-harvest drop in apples by use of dilute sprays of alpha-naphthalene-acetic acid." *Rep. E. Malling Res. Sta. for 1941*, 38-40.

——— (1943). "Sprays to control pre-harvest drop of fruit." *Rep. E. Malling Res. Sta. for 1942*, 47-8.

——— (1944). "Further trials with sprays to control pre-harvest drop." *Rep. E. Malling Res. Sta. for 1943*, 49-51.

——— (1945). "Sprays to prevent pre-harvest drop of fruit." *Rep. E. Malling Res. Sta. for 1944*, 118-19.

——— (1946*a*). "Experiments with growth substances for reduction of pre-harvest drop of fruit." *J. Pomol.*, **22**, 11-37.

——— (1946*b*). "Fruit fall and its control by synthetic growth substances." *Imp. Bur. Hort. and Plant. Crops, Tech. Commun.*, 18.

## BIOCHEMISTRY

# THE ROLE OF MINERAL NUTRITION IN THE ROOTSTOCK-SCION EFFECT

## A PROGRESS REPORT

By W. A. ROACH

with Appendices on methods of analysis by A. C. MASON and F. H. VANSTONE

The rootstock-scion effect was selected as the main line of work by the newly-formed Biochemistry Section in 1927, both because of its practical importance in horticulture and because of its general theoretical interest (Roach, 1929, 1930). As is well known, most fruit trees are built up of two different varieties or even species : a top or scion variety budded or grafted on another (rootstock) variety. This is found convenient in practice because many of the most valuable varieties of fruit, such as Cox's Orange Pippin apple and Doyenné du Comice pear, do not come true from seed and are not easily propagated on their own roots. They are, therefore, worked (budded or grafted) on varieties that do root freely. Such varieties have long been propagated for use as rootstocks. But each of these rootstocks influences the scion variety worked on it in many important respects, e.g. vigour of tree, precocity or lateness of fruiting, season of maturity of fruit, size and quality of fruit, resistance or susceptibility to insect pests, fungus diseases, etc. The qualities desirable for a particular horticultural purpose, however, are not found together in a single rootstock variety, but are usually scattered in a number of different ones. The plant breeder attempts to combine all these characters into a single seedling variety, but this is, at best, a slow process and may not in the end prove possible. The biochemist, on the other hand, tries to " explain " and imitate the desirable effects of rootstock ; and one of his practical aims is to make the best of existing horticultural material.

The fact that many of the effects of rootstock resemble those of soil type and artificial manuring suggested that the rootstock effect might be due, in some measure, to its influence on the mineral composition of the scion variety nourished by it. For a preliminary test of this possibility, use was made of trees of the same scion variety, but on two very different rootstocks, growing in two parallel rows with their roots ramifying, to a large extent, through the same soil. Each of these trees was separated into a number of different fractions, e.g. the leaves were separated into lamina and petiole plus midrib ; the current year's shoots were separated into wood and bark ; and the bark into four layers, viz. the cuticle ; a layer beneath the cuticle containing most of the chlorophyll ; beneath this a layer easily scraped from the fourth, which consisted largely of fibrous cells. Each fraction was ashed and the ashes were examined spectrographically in the carbon arc. Examination of the spectrograms suggested that the various fractions of the same tree differed widely in mineral composition, e.g. the chlorophyll containing fractions were much richer in iron than any others ; and, what is of even greater importance from the present point of view, corresponding fractions from different trees varied appreciably in composition according to the rootstock.

This result seemed reasonable in that all the mineral elements contained in the scion were absorbed from the soil and passed on to it by the rootstock, which consequently might well have an effect on the mineral composition of the scion. But the interactions between two different varieties (sometimes species), brought into unnatural union by budding or grafting, may well be complex—a possibility rendered the more likely by the fact that well over a score of mineral elements are involved on the one hand and at least an equal number of horticultural characters on the other. As complete a picture as possible of the mineral status seemed, therefore, to be desirable, even at the cost of slow progress. This argument was reinforced by the fact that at that time (1927) one element after another was being added to the list of those proved to be essential or beneficial to plants ; and there is no reason to suppose that the list is even yet complete. A difficulty of another type was also faced at the outset, namely, that some rootstock effects, though of great commercial importance, are subtle and difficult to define. For example, it is in the leaf that are built up all the organic materials out of which the whole tree is constructed, yet there is usually no marked difference between the leaves of two trees of widely different performance. The leaves of two trees of the same age, growing in the same soil, but

on different rootstocks, the one in full bearing and the other not yet producing a single fruit, commonly differ merely in depth or quality of green colouring and size. Such differences are small compared with the many differences induced by rootstock, already mentioned earlier in this note. Such subtle differences, however, are reminiscent of those between fields of corn of medium and high yield.

Two types of method have been developed to obtain a comprehensive picture of the effects of rootstock on the mineral status of the scion and the effects of this on horticultural performance. The first type consists of refined methods of analysis necessary to deal with the difficult problems presented by the many important, and potentially important, traces of elements in the presence of comparatively very large amounts of other (major) elements. The second type consists of methods for testing the effects of the elements, one or more at a time, on single trees or parts of trees.

The present state of the analytical methods will be stated briefly in two appendices that follow. Although any or all of these methods are likely to be improved, they are described briefly at this stage as a means of comparing notes with other workers engaged on these difficult analytical problems.

For testing the effects of elements on whole trees or parts of trees " injection " methods were developed, whereby the substances were caused to permeate parts of trees varying in size from the area between two neighbouring veins of a leaf up to a main branch or whole tree (Roach, 1938, 1939 ; Roach and Roberts, 1945). Such methods have the great advantage that the substance does not come in contact with the soil. When substances, such as copper sulphate, are applied to the soil most of them are absorbed by the solid soil particles and in their place other elements are liberated, any or all of which may be absorbed by the tree. In consequence, the effect on the tree may be in only small part due to the copper salt applied, but in comparatively large part due to the substances displaced by the copper from the soil. But it could not be assumed without trial that substances absorbed by the plant unnaturally through cuts made in their above-ground parts would be used by the plant in the same way as when they were absorbed naturally through the roots. The effects of the injection of substances of known nutrient value such as potassium nitrate were therefore studied and encouraging results were obtained. Analysis and injection were then developed as complementary methods for diagnosing mineral deficiency. In this way an immediately practical end was being served and at the same time the methods were being tested and refined for eventual application to the rootstock problem (Roach, 1940).

The general procedure was to analyse the leaves of trees of varying degrees of unsatisfactory performance in comparison with those of trees of highly satisfactory performance, and to note any apparent correlations between the content of particular elements and the commercial performance : then to test the effects of such elements (not always single ones) by injecting them into plants of poor performance. In practice it has often proved convenient to inject ten or a dozen elements each into a number of separate shoots at the same time that samples are taken for analysis. Thus the results of both analysis and injection might both be obtained in two or three weeks, and by quite independent means two " pictures " obtained of the mineral status of the plants being studied, which can then be compared. This joint use of the two methods was found particularly advantageous when the writer was in South Africa and sent samples to Major Thompson for analysis at East Malling. Before going to South Africa improvement in leaf colour had been obtained on numerous occasions as a result of injecting iron, manganese, zinc, boron, copper and nickel into leaves of trees of medium performance, but there was no proof that such " improvements " in leaf colour were of any importance in respect to tree performance. In South African orchards, however, there were numerous examples of a continuous variation along a row from apparently perfect horticultural performance to dead or dying trees ; and in many such cases the combined analysis and injection work established the cause to be a deficiency of manganese or zinc, and there was strong presumptive evidence that even the milder degrees of deficiency were of commercial importance. Such evidence strengthened the suspicion that similar " improvements " in leaf colour obtained in South Africa to the other trace elements, iron, boron, copper and nickel, might also indicate deficiencies of commercial importance, and that the similar results obtained in England with all six trace elements mentioned above might also indicate such deficiencies.

Work reported briefly in the recent Annual Reports (Roach, 1944 and 1945) proved that spraying with all six trace elements raised the yield of three agricultural crops to an economically important extent.

It has already been stated that apparently beneficial responses have been obtained as a result of the injection of these six elements into fruit trees. It is necessary therefore to take at least these six trace elements, as well as the elements nitrogen, phosphorus, potassium, calcium and magnesium into account ; and almost certainly other elements will have to be added to the list.

Although much further work is necessary on analytical methods, they were used in 1946 to make a preliminary survey of the effect of rootstock on the mineral composition of the scion worked on it. A plantation designed to test the effects of both rootstocks and artificial manuring on two varieties

of apples (Hoblyn, 1941) provided excellent material for this purpose. Samples were taken from Cox's Orange Pippin trees on rootstocks M. V, IX and XII from the plots receiving all combinations of nitrogen and nil, humus and nil ; i.e. four different treatments. These were repeated on four different plots. The rootstock comparison was therefore repeated sixteen times. The results are shown in the table below.

TABLE.

ELEMENTS ARRANGED ACCORDING TO DESCENDING AMOUNT CONTAINED IN COX'S ORANGE PIPPIN LEAVES ON THE THREE ROOTSTOCKS M. V, IX AND XII.

| | |
|---|---|
| (Mg), B, Fe | XII > V > IX |
| (Ca), (Sr) | IX > V > XII |
| (K) | XII > IX > V |
| Mn | IX > V, but XII variable. |
| P | variable. |

For elements shown in brackets, results are less reliable.

Thus M. XII induces the highest content of magnesium, boron and iron, and IX the lowest, V being intermediate in this respect. The order for calcium and strontium is the reverse. The order for potassium is different, viz. XII, IX, V. The results for the elements so far mentioned were remarkably consistent, with hardly an aberrant one. Manganese gave a further type of result. Leaves on IX always contained more than those on V, but those on XII were extremely variable, some being higher than those on IX and some lower than those on V. The phosphorus figures varied from 0·2 to 0·4 per cent., but there was no suggestion of the rootstocks falling into any order. Phosphorus and boron were determined chemically and the figures are probably reliable. Iron was determined quantitatively by a chemical method and qualitatively by the spectrographic method. The results were in excellent agreement. The remaining elements, magnesium, calcium, strontium and potassium were determined visually from the spectrograms. These spectrographic results must be considered tentative because of the possibility of interference effects on line density by other elements. One of the most seriously interfering elements—phosphorus—was so variable in amount that it can hardly have had any serious systematic effect on the density of the lines of calcium, strontium or magnesium and even less on those of potassium. Even with these reservations, it is safe to conclude from these results that the rootstocks exerted a considerable effect on the mineral composition of the scion. This effect was not obliterated by an application of ammonium sulphate or of humus to the soil and it showed up on both types of soil that occur on the experimental plantation. This preliminary survey will therefore be extended to include more than one variety on a wider range of rootstocks and on a wide range of soils.

Results already obtained on annual crops (Roach, 1946) suggest that the interpretation of the results of leaf analysis and injection is likely to be anything but straightforward. Not only may elements, such as iron, be in part in forms useless to the plant, but the effect of one element may be conditioned by the amount of another element present. But a start has been made by other workers (Bolas, 1946) on determining the effects of injected substances on certain physiological functions of the plant. This should provide a further valuable method for the present purpose.

Some time may still elapse, therefore, before more than tentative conclusions can be drawn ; but the results already obtained are in harmony with the conclusions drawn from horticultural experience, that rootstocks vary, not only in the total amount of nourishment they pass on to the scion worked on them, but also in the quality of that nourishment.

**Summary.**

Past work on, and the present position of, the rôle of mineral nutrition in rootstock-scion effects are briefly reviewed. The chemical and physical methods of analysis employed are given in two appendices.

Results of preliminary work prove that the rootstock exerts a considerable effect on the mineral composition of the scion worked on it. This effect is not merely quantitative ; the relative proportions of a number of the elements are influenced to a considerable extent.

## Appendix I

## CHEMICAL METHODS OF ANALYSIS

By A. C. MASON

In carrying out a chemical analysis of plant material there are three stages to be considered, namely, the destruction of organic matter and preparation of a solution of the elements to be determined, the isolation of each element and finally, the estimation. Methods have been worked out for seven elements (N, P, K, Ca, Mg, Fe, B) and work is still in hand on the estimation of copper and zinc, while manganese and nickel will be dealt with afterwards.

Starting with the ground dry material, there are two general methods for destruction of organic matter, each of which has its special application according to the properties of the element under consideration.

Ashing is a very simple method for destruction of organic matter and it has been adopted for those elements which are not volatile below 500° C., which applies to all the elements mentioned except nitrogen.

Several digestion methods described in the literature (Lindner, 1944 ; Piper, 1942 ; Belcher and Godbert, 1945) have been investigated, but none proved so convenient as simple ashing. The perchloric acid, nitric acid digestion method (Piper, 1942) does not cover nitrogen and, while it gives satisfactory results, difficulties arise with the high acidity of the final solution and, moreover, any acid digestion method is unsatisfactory for boron which is volatile under such conditions. The simple ashing method has sometimes been criticized for giving low results because some of the minor elements may be rendered insoluble (Piper, 1942). We have been unable to detect such an effect where the ashing procedure is controlled. The only element out of the seven mentioned which is lost is nitrogen, and this is determined by digestion of a separate portion of dry plant material. The method recommended by Belcher and Godbert (1945) is quite satisfactory. For routine work the nitrogen is estimated by digesting with sulphuric acid and hydrogen peroxide and then almost neutralizing the acid digest with sodium hydroxide and adding Nessler reagent. The intensity of colour developed is estimated with a Spekker absorptiometer and the nitrogen determined by reference to a calibration chart prepared using standard ammonium chloride solution. For more accurate estimations of nitrogen, the standard volumetric procedure is adopted.

All other elements are estimated using a solution prepared as follows :

100 mg. of ground dry material is weighed into a small silica crucible, which is covered with a lid and placed in a muffle furnace. The temperature is raised rapidly by passing a current of 5 amps. for 5 minutes and then reducing to 3 amps. The temperature is maintained at about 400° C. for 1 hour and the crucibles are then removed. Slow combustion of organic matter is ensured by restricting the supply of air to the contents of the crucible and by raising the crucibles off the floor of the furnace. In the presence of excess air, even at relatively low ambient temperatures of 350° C., local overheating occurs when particles of carbon glow momentarily. After cooling, about 0·5 ml. of N. hydrochloric acid is carefully added to the ash by means of a dropping pipette fitted with a teat, evaporated to dryness in a boiling water oven and a further 0·5 ml. of acid added. The crucible and contents are gently heated to about 60° C. on a hot plate and the contents of the crucible transferred, using the dropping pipette to a 1 ml. graduated flask, then, using the same dropper, the crucible is washed with water which is also transferred to the flask. The solution is made up to volume and and thoroughly mixed. From this 1 ml. of solution five aliquots each of 0·1 ml. may be withdrawn for determination of K, Ca, Mg, Fe, Mn, two aliquots each of 0·05 ml. for determinations of phosphate and boron and one aliquot of 0·2 ml. for determination of copper and zinc.

Of the elements under consideration, a preliminary separation has been shown to be unnecessary for P, K, Ca, Mg, Fe, B, as the final method of estimation is sufficiently specific to give reliable figures of the order of accuracy required, i.e. $\pm 5$ to 10 per cent. of the element present. So long as reactions take place under acid conditions there is no difficulty, but any method of estimation carried out at a pH where precipitation of phosphates occurs is not satisfactory without a preliminary separation.

Phosphate is determined on an aliquot of the test solution using the well-known molybdenum blue method with hydroquinone and sodium sulphite as reducing agents (British Drug Houses *Book of Organic Reagents*, ninth edition). The colour intensity is measured on the Spekker and very satisfactory results are obtained.

For potassium a rapid turbidometric method has been developed using sodium cobaltinitrite. The method described by Tinsley and Pizer (1945) was tested with unsatisfactory results. The cause of variability was traced to the keeping properties of the sodium cobaltinitrite solution, and was overcome by preparing a finely divided suspension of the reagent in ethyl alcohol. The suspension

was measured by means of a pipette into the reaction tube, which was shaken vigorously with the aliquot of test solution and the light transmission measured in the Spekker immediately. The method has proved fairly reliable and rapid for routine work, but further experience with it is necessary to assess its value properly.

Calcium is determined on an aliquot of the test solution by the usual oxalate method completed volumetrically using standard potassium permanganate.

A thoroughly satisfactory method for magnesium is difficult to find, but fair results have been obtained using the Titan Yellow method of Stross (1942). The interference by calcium is easily eliminated by the use of calcium chloride in the test reagent and it has been shown that under these conditions there is no serious interference by iron. The intensity of pink colour is measured by the Spekker and referred to a standard curve.

Iron is satisfactorily determined by means of the pink colour developed with αα'dipyridyl. A strongly buffered solution (molar) has been shown to be necessary.

The method adopted for boron is based on a method described by Owen (1946). An aliquot of the test solution is mixed with quinalizarin solution in sulphuric acid. The method of preparation and storage of the reagent solution is important if moisture is to be properly excluded. The blue colour is estimated by means of the Spekker. The absorption cell is covered with a ground glass plate during the measurement. This method has proved satisfactory during the limited period it has been under test.

The work in hand for the estimation of copper and zinc is based on the extraction by means of chloroform of their salts with the organic reagent dithizone (E. B. Sandell, 1944). The organic matter is destroyed and the solution of copper and zinc ions finally obtained is polarographed (A. Walkley, 1942).

The chemical methods of analysis have been sketched briefly in this paper, because a detailed description would be premature. In due course when various difficulties have been overcome they will be published in full.

## Appendix II

## PHYSICAL METHODS OF ANALYSIS

**By F. H. VANSTONE**

So far only one physical method of analysis has been employed. The spectrograph is at present used to provide a picture of the nutritional status of plant material so far as the elements Ca, Sr, Na, K, Mn, Mg and Fe are concerned. Thus used, its utility lies in its ability to provide this picture in a short time with the use of a small amount of material, 25 milligrammes or less. To do this, use is made of the fact that when these elements are made to absorb the thermal energy of an oxy-acetylene flame they emit this energy in the form of light, each element giving its own characteristic light or spectrum.

For any sample to provide a consistent picture on replication it must be presented to the flame in a suitable, reproducible form, so considerable attention is directed to the problem of cleaning, drying and grinding the material.

For the present degree of sensitivity, cleaning by rubbing the plant material (usually leaves) with clean muslin or a rotating soft brush appears to be adequate. Similarly, drying in an oven at 80° C. or between two electrically heated blankets is reasonably satisfactory. Grinding is carried out while the leaves are still warm, in a warm agate mortar, mechanically or by hand. Most materials are thus brought to a reasonably homogeneous fine powder. Developments in the method envisaged at the moment, which it is hoped will increase its reproducibility and sensitivity, will require the degree of homogeneity to be taken a stage further. Since ease of grinding is dependent to a large degree on the rate of drying of the leaves, it will thus be necessary to dry them more rapidly but without any tendency to char. It is hoped to achieve this by drying the leaves in a current of hot air.

25 mg. of the dry powder are folded between specially pure filter paper to form a spill, the powder being evenly distributed over a length of 3 cm., the whole operation being carried out so that neither the powder nor the paper is touched by hand. The spill is then heated in an atmosphere of ammonium chloride at a temperature of about 350° C. for two minutes. This serves the purpose of considerably reducing the quantity of organic material both in the filter paper surrounding the powder and in the powder itself, and of converting the metallic elements in the powder to their chlorides. The higher volatility of the chlorides of the metals results in a higher light emission compared with the carbonates otherwise formed.

The charred spill is pushed along a platinum-iridium trough parallel to the axis of the spectrograph into the flame by a xylonite pusher at a constant speed of 4 cm. per minute. The light emitted by the spill enters the spectrograph through the slit and so produces the spectrum on the photographic plate. The density of a line in the spectrum gives a measure of the amount of the element producing it present in the original plant material.

The above method has recently been described in detail (Roach, 1946). Thus used the following minimum quantities of the various elements can be detected :

| | | |
|---|---|---|
| K | .. .. | 0·02 per cent. |
| Mg | .. .. | 10 p.p.m. |
| Mn | .. .. | 2 p.p.m. |
| Fe | .. .. | 20 p.p.m. |
| Cu | .. .. | 20 p.p.m. |

Their occurrence on a dry weight basis in healthy plant material is of the following order :

| | | |
|---|---|---|
| K | .. .. | 1 per cent. |
| Mg | .. .. | 0·2 per cent. |
| Mn | .. .. | 100 p.p.m. |
| Fe | .. .. | 100 p.p.m. |
| Cu | .. .. | 1 p.p.m. |

In flame spectrographic methods one factor which seriously limits both the sensitivity and accuracy of estimation is the background spectrum provided by the flame. Thus every modification which enables the sample to be consumed in the flame in a shorter time will be a step in the right direction. Any attempt to feed the present type of spill into the flame at a faster rate results in reduced sensitivity because the limited rate of energy dissipation in the flame results in a reduction of the flame temperature in the region of the spill.

If, however, organic material is first removed by ashing and the spill made up with the ash, since the latter takes up a much smaller volume than the original plant material, it can be distributed over a length of 2 mm. and burnt in 3 seconds. This does result in a considerable reduction in the flame background, particularly in the region of the Cu and Mo lines and enables the Cu normally present in healthy plant material to reveal its presence.

The rate of feed, above which temperature reduction takes place, is now controlled by the bulk of the filter paper rather than by the plant material.

Thus an attempt was made to present the chlorided ashed material to the flame without the encumbrance of the filter paper. This was achieved by forming a disc of the metallic chlorides in a loop 2 mm. in diameter of very fine wire. When this disc was plunged into the flame the supporting wire melted and the disc fell away before it had become activated. This result was obtained using wire of both platinum and tungsten.

Even with the reduced background corresponding with an exposure of 3 seconds, the elements Co, Ni, Mo, etc., are not shown up, presumably owing to the fact that the intensity of their light emission is below the threshold of the photographic plate. It thus becomes necessary to reduce the burning time still further so that, consistent with no reduction in total emission (i.e. product of intensity and time), the intensity will be correspondingly increased up to and beyond this threshold. It is thus proposed to continue the attempt to reduce the exposure time to a second or even less. Should this be successful, it will then be possible to reduce considerably the quantity of plant material necessary for one exposure, a development which is practicable at this stage so far as the major elements are concerned.

There are two very serious drawbacks to the use of the spectrograph for quantitative determinations of a high order of accuracy. The sensitivity of the photographic emulsion varies in a random fashion over the plate and from plate to plate. Since determinations are made by comparison with the density of spectra produced by known amounts of the different elements, it becomes necessary to calibrate each individual plate, and to replicate each determination to the highest convenient degree. Secondly, when a sample is introduced into the flame the various elements interfere with one another's emission. There are at least two forms of interference which can broadly be classified as chemical and physical.

*Chemical.* Element A, burnt in the flame by itself produces a line of density $D_1$. If element A is introduced into the flame mixed with element or compound B, A and B will combine under the conditions prevailing in the flame to form a compound whose volatility will be different from that of A. This changed volatility will result in the production of a line whose density $D_2$ will be greater or less than $D_1$. The amount by which $D_2$ differs from $D_1$ will vary with the amount of B present in the

original mixture. Similarly A will have an effect on the density of the line produced by B. This effect is somewhat reduced by the conversion of all the metallic elements to their chlorides, but it does still seriously reduce the accuracy of the estimation of some of the elements. The behaviour of calcium in the presence of phosphate is an example of this chemical effect. The emission of calcium is much reduced by phosphate, the reduction varying considerably with the amount of phosphate present.

*Physical.* If element A is much more volatile than element B, when a mixture of A and B is introduced into the flame, A tends to volatilize more quickly than B, thus reducing the energy available to activate B. The line given by B will thus be less dense than the line it would give in the absence of A. An example of this is the effect of Na on Mn.

Theoretically there would appear to be no reason why every element should not interfere with the emission of all the other elements present in a mixture.

Before a really reliable quantitative method can be put into operation, it will be necessary to make a complete study of the mutual interferences between all the elements present in plant material and to evolve correction factors where the effects are large enough to reduce the accuracy of the estimation of any element.

## References.


British Drug Houses (1946), *Book of Organic Reagents.* Ninth ed., pp. 89 and 76.

Belcher, R., and Godbert, A. L. (1945). "Semi-micro Quantitative Organic Analysis." Longmans, Green & Co., London, p. 89.

Bolas, B. D. (1946). "Physiological effects of Trace Elements." *Rep. E. Malling Res. Sta. for 1945,* 89.

Hoblyn, T. N. (1941). "Manurial Trials with Apple Trees at East Malling, 1920-39." *J. Pomol.,* **18**, 325-43.

Lindner, R. C. (1944). "Rapid Analytical methods for some of the more common inorganic constituents of plant tissues." *Plant Physiology,* **19**, 76.

Owen, E. C. (1946). "The determination of Boron by the use of Quinalizarin." *Analyst,* **71**, 210.

Piper, C. S. (1942). "Soil and Plant Analysis." University of Adelaide, Adelaide, pp. 261 and 258.

Roach, W. A. (1929). *Rep. E. Malling Res. Sta. for 1928,* 93.

——— (1930). *Rep. E. Malling Res. Sta. for 1929,* 63.

——— (1931). *Rep. E. Malling Res. Sta. for 1930,* 83.

——— (1938). "Plant Injection for diagnostic and curative purposes." *Imp. Bur. Hort. and Plant. Crops, Tech. Comm.* 10, 27-30.

——— (1939). "Plant Injection as a Physiological Method." *Ann. Bot.* N.S. **3**, No. 9, 155-226.

——— (1940). "Diagnosis of Mineral Deficiencies and Excesses by Systematic Leaf Injection and Analysis." *Rep. E. Malling Res. Sta. for 1940,* 51-8.

———, and Roberts, W. A. (1945). "Further work on plant injection for diagnostic and curative purposes." *J. Pomol.,* **21**, 7.

——— (1945). "Mineral Deficiencies in Agricultural and Horticultural Crops." *Rep. E. Malling Res. Sta. for 1944,* 43-60.

——— (1946). "Mineral Deficiencies in Agricultural and Horticultural Crops. II." *Rep. E. Malling Res. Sta. for 1945,* 83-8.

——— (1946). "A Flame Method of Spectrochemical Analysis." *J. Soc. chem. Ind.,* **65**, 33.

Sandell, E. B. (1944). "Colorimetric determination of traces of Metals." Interscience Publishers Inc., New York, p. 72.

Stross, W. (1942). *Analyst,* **67**, 317.

Tinsley, J., and Pizer, N. H. (1945). "The Morgan Rapid Method of Soil Testing, Part III. Use of the Spekker Absorptiometer for estimating potassium." *J. Soc. chem. Ind.,* **64**, 182.

Walkley, A. (1942). *Aust. J. expt. Biol. and med. Sci.,* **20**, 139.

# SUSPECTED BORON DEFICIENCY IN APPLES IN BRITAIN

By B. F. G. LEVY

## Introduction.

Although boron deficiency in apples, characterized by " corkiness " of the flesh of the fruit, has caused serious economic losses in many overseas countries, including New Zealand (Atkinson, 1935) ; Canada (McClarty, 1936, and Young and Bailey, 1936) ; Finland (Jamalainen, 1930) and elsewhere ; and lack of boron is of recognized importance in the British Isles in other crops such as beet, there is as yet no record in this country of this deficiency occurring on apple trees.

Since Bitter Pit of apples, which does occur in this country, exhibits somewhat similar symptoms to those of " cork ", the effect of boron treatment on Bitter Pit was tested by Levy and Roach in 1936. This trial, as already described (Levy and Roach, 1937), was carried out, using the liquid tree injection method, on 16 trees of 14-year-old Northern Spy on M. IX, which were known to have borne fruit affected with Bitter Pit. The treatments were :—

1. Boric acid, $H_3BO_4$ (0·1 per cent.).
2. Boric acid, $H_3BO_4$ (0·1 per cent.) + potassium phosphate, $K_2HPO_4$ (0·5 per cent.) + urea, $CO(NH_2)_2$ (0·25 per cent.).
3. Potassium phosphate, $K_2HPO_4$ (0·5 per cent.) + urea, $CO(NH_2)_2$ (0·25 per cent.).
4. Not injected.

The amount absorbed varied from tree to tree, but averaged 3 litres of solution. This represents a dose of about 3 gm. of boric acid (0·5 gm. boron), 15 gm. of potassium phosphate, and 7·5 gm. urea per tree.

As was reported in that paper, the boron treatments had no effect on the incidence of Bitter Pit. This negative result was confirmed by the work of Wallace and Jones (1940). In their work also, tree injection with boron did not cure the trouble.

This note deals with records made the following season (1937) on fruit from the same 16 trees without further treatment. Symptoms observed in 1937, that differed from those shown in 1936, appeared to be reduced in severity by the boron injection. Before these records are discussed, a description will be given of the fruit symptoms in the two years.

## 1936 Symptoms.

The pits observed in 1936 were visible while the fruit was still on the trees and corresponded closely with the descriptions of Bitter Pit as given by Carne,* and Hill (1937).

The pits took the form of a well-defined depression in the surface of the apple, about 1 mm. in depth and usually from 2-5 mm. in diameter, but sometimes more, usually more or less circular. The depressed area was usually rather darker than the surrounding ground colour. The pits were present either singly or in groups ; when in groups they were usually small.

The pits appeared to have resulted from the death and collapse of the tissue immediately beneath the skin ; the dead area corresponding with that of the superficial pit. The dead area was about 1 mm. in depth and was brown and dry. A pit could readily be distinguished from a bruise by holding the apple near the ear while pressing the surface. A pit gave a crepitus, whereas little or nothing could be heard with a bruise.

When affected apples were cut across equatorially the pits could be seen clearly in section. No necrotic areas were observed which did not also show on the surface ; nor were any other types of internal disorders noted.

## 1937 Symptoms.

The following year, 1937, was an off-year for these trees and the crop small. No pits were seen on the fruits while they were still on the tree, and few pits of the 1936 type were seen when recording, either on the surface or in section. But when the apples were peeled another type of symptom became apparent.

* " Small to moderately large dry brown lesions in flesh from core line to the skin which is frequently involved. Surface symptoms are discoloured spots showing through the skin or brown depressed pits with brown flesh lesions beneath."

This symptom was in the form of necrotic areas *beneath* the skin, but *not in contact with it*, sometimes down to 4 mm. below the skin. Their diameter was between 1 and 2 mm., and their colour was rather dark brown. They occurred mainly between the equator and the calyx, sometimes scattered all round the circumference and sometimes localized in groups in an area of 2 or 3 square cm. But no trace of the symptom could be seen on the surface of the fruit, nor were they very noticeable when the apple was cut across equatorially ; they only became obvious when the apples were peeled.

These symptoms were not observed in 1936, but they may have been present and escaped notice. In that year the apples were not peeled, but even if they had been, this 1937 type of pit would have been inconspicuous in the presence of the much more striking surface pits. The fact that a few of the 1936 pits were seen in 1937, proves that the two symptoms may occur together.

Thus, the symptoms seen in the two years were quite distinct ; the one occurring in 1936 appeared typical of Bitter Pit as described by Carne and Hill, as it occurs in Australia and Canada ; the other did not correspond with any symptoms described by them.

**Records and Results, 1937.**

The apples were picked on 15th October, 1937, when judged to be mature. Each treatment had been repeated on four trees, but the number of fruits on each tree was insufficient to form a satisfactory experimental unit ; the crops from those trees that received the same treatment were therefore amalgamated, for recording and storage. The numbers and weights of the fruit from each treatment for 1936 and 1937 are given in Table I. The apples were kept in natural storage in trays in a packing shed. On 12th December, a random sample of 20 apples was removed from each treatment for recording ; the remainder were kept in store until the second recording on 18th January.

In Table II these two recordings are designated " count 1 " and " count 2 " respectively. Against each count, the total number of apples in the recorded sample is given, together with the percentage of affected apples.

TABLE I.

TOTAL CROP FOR EACH OF THE TREATMENTS IN 1936 AND 1937, SHOWING THE NUMBER OF FRUITS AND THEIR WEIGHT IN LBS.

| | Non-Boron. | | | | | Boron. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1936. | | 1937. | | | 1936. | | 1937. | |
| | | No. | Wt. in lbs. | No. | Wt. in lbs. | | No. | Wt. in lbs. | No. | Wt. in lbs. |
| Control .. .. | | 355 | 107 | 116 | 38 | Boric acid | 209 | 59 | 180 | 58 |
| NPK .. .. .. | | 226 | 62 | 137 | 42 | Boric acid +NPK | 415 | 109 | 104 | 31 |
| Total .. .. | | 581 | 169 | 253 | 80 | Total | 624 | 168 | 284 | 89 |

TABLE II.

EFFECT OF INJECTION TREATMENTS ON THE NUMBER OF AFFECTED APPLES IN 1937, SHOWING PERCENTAGE AFFECTED. (FIGURES IN BRACKETS SHOW THE NUMBER OF APPLES IN THE SAMPLE.)

| | Non-Boron Count. | | | | Boron Count. | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | Total. | | 1 | 2 | Total. |
| Control .. | 50 (20) | 39 (36) | 42·8 (56) | Boric acid .. | 30 (20) | 22·2 (27) | 25·5 (47) |
| NPK .. .. | 50 (20) | 36·2 (36) | 41 (56) | Boric acid +NPK | 40 (20) | 20 (20) | 32·5 (40) |
| Total .. .. .. .. .. | | | 43·8 (112) | Total .. .. .. .. .. | | | 28·0 (87) |

At each recording the apples were divided into three grades according to the severity of the symptoms :

Grade 1. Apples with 1 to 20 pits.
Grade 2. ,, ,, 20 to 50 ,,
Grade 3. ,, ,, over 50 ,,

The numbers of apples in each grade for each treatment were counted and these figures have been treated in a roughly quantitative manner by multiplying the numbers in each grade by 1, 2 and 4, respectively. When these products are added, a single figure is obtained which is shown in Table III, expressed as a percentage of the total fruit in the sample.

TABLE III.

EFFECT OF INJECTION TREATMENTS ON THE DEGREE OF AFFECTION IN 1937, SHOWING THE "QUANTITATIVE FIGURE".

| | Non-Boron Count. | | | | Boron Count. | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | Total. | | 1 | 2 | Total. |
| Control .. | 80 | 86 | 84 | Boric acid .. | 35 | 59 | 49 |
| NPK .. | 105 | 80 | 89 | Boric acid + NPK | 65 | 50 | 57·5 |
| Total .. .. .. .. .. | | | 87 | Total .. .. .. .. .. | | | 53 |

**Discussion.**

It will be seen from Table II that the percentage of affected apples for the two boron treatments (boric acid and boric acid plus NPK) together is 28 per cent. as compared with 43·8 per cent. from the two non-boron treatments (NPK and control).

On the other hand there is little difference between the percentage (37·5) of the two treatments containing NPK (boric acid plus NPK and NPK) compared with that (35) for the two without NPK (boric acid and control).

The total crops carried by the boron and non-boron treated trees were 168 and 169 lb. in 1936, and 89 and 80 lb. in 1937 respectively. The yields on boron treated and untreated were, therefore, comparable.

No explanation can be given for the fact that the percentage of affected fruit recorded at the second was less than at the first recording, but depth of peeling would seem a possible cause for such a systematic difference.

The amounts given by Wallace and Jones (1940) for the boron content of the apples not treated with boron, viz. 17·4 and 16·8 p.p.m. B, though low, are not definitely inadequate ; but trace elements commonly occur in large amounts in physiologically deficient plants, in forms useless to the plant.

These results (Table II) were submitted to the Statistical Section, who carried out an analysis of variance. This showed that the difference between the boron and the non-boron treatments was significant, as also was that between Count 1 and Count 2. In both cases the significant difference was 8·3.

There is therefore an indication that the 1937 symptoms were reduced in intensity by boron treatment.

There are other reasons for suspecting at least a mild boron deficiency in the same plantation : for example Gayner (1941) obtained a definitely beneficial response to the injection of boric acid into pear leaves, and symptoms were observed in cherries resembling closely those cured elsewhere by a soil application of boric acid (Thompson, 1944).

**Summary.**

In 1936, sixteen Northern Spy apple trees were injected with boric acid and an " NPK " mixture to test their effect on the incidence of Bitter Pit. The symptoms consisted of surface pits and were not affected by the boric acid treatments.

In 1937, different symptoms appeared on the same trees. They were not visible on the surface and did not correspond with normal Bitter Pit symptoms.

The severity of these symptoms appeared to be reduced by the boric acid treatments. It is suggested tentatively that this disorder belongs to the " cork " class and results from boron deficiency. This is in harmony with other facts that suggest that mild boron deficiency may occur in British apple trees in which it has not so far been recorded, as well as in other crops in which it is well known.

**Acknowledgement.**

The writer is much indebted to Dr. W. A. Roach for valuable help.

## References.

Atkinson, J. D. (1935). " Progress report on the investigation of corky-pit of apples." *N.Z. J. Sci. Tech.*, **16**, 316-9.

Carne, W. M. " Non-parasitic and functional disorders of apples. A tentative classification." (Unpublished).

Gayner, F. C. H. (1941). " Studies in the non-setting of pears. VI." *Rep. E. Malling Res. Sta. for 1940*, 50-5.

Hill, H. (1937). " Functional Disorders of Apples on the Tree." *Rep. E. Malling Res. Sta. for 1936*, 180-2.

Jamalainen, E. A. (1936). " Boorin vaikutus kuoppataudin esiinty-miseen omenissa." (The effect of boron on the occurrence of cork disease in apples.) (Finnish-English Summary, 4 pp.), *Valt. Maatalousk. Julk*, **89**, 19.

Levy, B. F. G., and Roach, W. A. (1937). " Preliminary injection experiments on Bitter Pit in Apples." *Rep. E. Malling Res. Sta. for 1936*, 183-4.

McLarty, H. R. (1936). " Tree injections with boron and other materials as a control for drought spot and corky core of apple." *Sci. Agric.*, **16**, 625-33.

Thompson, S. G. (1944). " Abnormal ripening of cherries." *Rep. E. Malling Res. Sta. for 1943*, 51.

Young, L. C., and Bailey, C. F. (1936). " Progress report on the investigation of corky, core of apples." *Sci. Agric.*, **17**, 115-27.

Wallace, T., and Jones, J. O. (1940). " Boron in relation to Bitter Pit in Apples." *J. Pomol.* **18**, 161.

# TREE INJECTION I

## THE ESTIMATION OF DOSAGE IN RELATION TO TREE SIZE

By B. F. G. LEVY

**Introduction.**

The following note describes attempts to determine tree size as a basis for liquid injection dosage. Various methods have been used previously, for instance Bennett (1931) published a dosage table for solid injection that has been used successfully by many workers. In this, dosage was based on diameter of main stem. A graph (Fig. 1) has been drawn to show the relationship between dosage and cross sectional area of stem calculated from this table. It shows that dosage is directly proportional to cross sectional area. Bennett does not state how this table was prepared, whether from empirical data or otherwise.

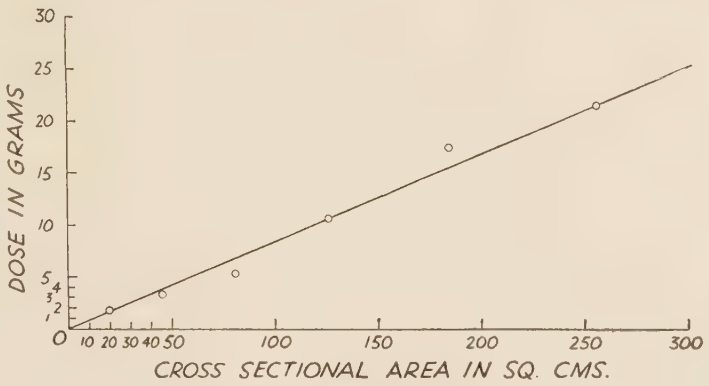


FIG. 1.

Showing the relationship between Dose and Cross Sectional Area, as derived from Bennett's table.

The procedure employed by Roach (1938) for liquid injection was to allow a tree to absorb until the first signs of leaf scorch appeared, when the injection was stopped and the amount thus absorbed was called the " maximum safe dose ". Marked responses were obtained by him in 1934 on trees whose doses were determined in this manner. This method thus appears to have yielded a sufficiently close approximation to the optimum dose for preliminary work. It has the advantage of being estimated comparatively quickly, since the maximum leaf scorch commonly appears within a few hours of the completion of injection ; whereas the greater part of the season would be necessary for the determination of optimum dose based on the effects on growth or quality.

In the experiments to be described, it will be shown how this basic principle of " maximum safe dose " can be applied more rapidly and more safely than heretofore, when used in conjunction with estimations based on the size of the tree.

**Comparison of Tree Size.**

Two Lane's Prince Albert trees were used for comparing three methods of determining tree size.

1. One tree was made up of 9 main branches of similar size, the other was estimated to consist of 37 such branches. The ratio of their size from this comparison was therefore 9 : 37 or about 1 : 4·1.

2. Their size was also compared by estimates of the cubic contents of the heads of trees calculated from measurements of the height above the crutch and the branch spread in two directions at right angles. By this method the ratio was found to be 1 : 3·2.

3. Finally by comparing the cross sectional area of the main stem of the two trees, the ratio between them was found to be 1 : 3·1.

Thus the results given by the three methods do not differ widely from each other ; the last method, however, is by far the most convenient, as it is readily obtained from the " girth measurement " which is measured annually as a routine for every tree on this Station.

**Comparison of Dose with Tree Size.**

1. In July, 1935, nine Lord Derby mature bush trees, whose girths varied from 37 to 27 cm. were injected with the following " complete " nutrient solution :

| | |
|---|---|
| Potassium phosphate ($K_2HPO_4$) .. | 0·25 gm. |
| Urea .. .. .. .. .. | 0·25 gm. |
| Water .. .. .. .. .. | 100 c.c. |

which gives a total concentration of 0·5 per cent.

The maximum safe dose for one of these trees was estimated by comparison with neighbouring trees that had already been injected. The dose for each of the remaining trees was calculated in relation to this tree and made proportional to the cross sectional areas of the main stems.

Table I shows the size of each tree and the dose, together with the amount of resulting leaf scorch.

TABLE I.

LEAF SCORCH, RESULTING FROM DOSAGE PROPORTIONAL TO CROSS SECTION OF STEM. LORD DERBY APPLES.

| Cross section sq. cm. | Dose litres. | Leaf scorch. |
|---|---|---|
| 67·0 | 6·9 | None |
| 72·0 | 7·5 | Slight |
| 89·2 | 9·3 | Trace |
| 92·0 | 9·5 | None |
| 92·0 | 9·5 | None |
| 103·5 | 10·5 | None |
| 121·0 | 12·6 | Slight |
| 125·0 | 13·0 | Slight |
| 132·0 | 14·0 | None |

It will be seen that the larger trees are not more or less seriously scorched than the smaller trees, thus suggesting that each tree had received approximately its maximum safe dose.

2. In June, 1936, some young Lane's Prince Albert trees on rootstock M. IX were injected with the same nutrient solution as above, but at 1 per cent. concentration, and were allowed to absorb until scorch first appeared. After a few days all were damaged, some badly. The doses absorbed by these trees are plotted against cross sectional area, on a graph, Fig. 2. It was found possible to draw a straight line A from the origin of the graph through these plotted points, so as to separate most of those for the badly damaged trees, from those for the less damaged trees. This also suggests that dosage should be proportional to the cross sectional area of the main stem. A second line B drawn from the origin separates damaged from undamaged and should represent the maximum safe dose for these trees. It was noted that this second line B would give this dose as 0·5 gm. of total salt, for every sq. cm. cross sectional area.

3. At the same time some similar neighbouring Cox's Orange Pippin trees on rootstocks M. V and M. I were injected with the same nutrients at 0·5 per cent. concentration. When these doses are also plotted, a similar line for the maximum safe dose is obtained (Fig. 2).

4. Mature Lane's Prince Albert trees were injected with the same nutrients (1 per cent.). These comprised trees of many different sizes, ranging from dwarf trees on M. IX to vigorous trees on M. XII. The doses obtained from these trees were plotted (Fig. 3) and the alignment of their points also agreed with a maximum safe dose of 0·5 gm. per sq. cm. of cross sectional area.

These results obtained from four separate sets of trees of three different varieties and ranging in cross sectional area from 1 to 300 sq. cm. seem to justify the following conclusions :

(*a*) that the ratio between maximum safe doses for any two bush apple trees was approximately the same as that between the cross sectional areas of their stems ;

(*b*) that the maximum safe dose was (at least for these trees and for this solution) approximately 0·5 gm. per sq. cm. cross sectional area ;

(*c*) that this method of estimation of tree size might prove to be a useful practical method in future injection experiments.

These deductions were put to the test in the experiment described below.

**Trial of the Method.**

For this experiment use was made of 132 trees of the variety Duchess' Favourite on stock M. IX. In size they were intermediate between the young Lane's Prince Albert trees on M. IX mentioned

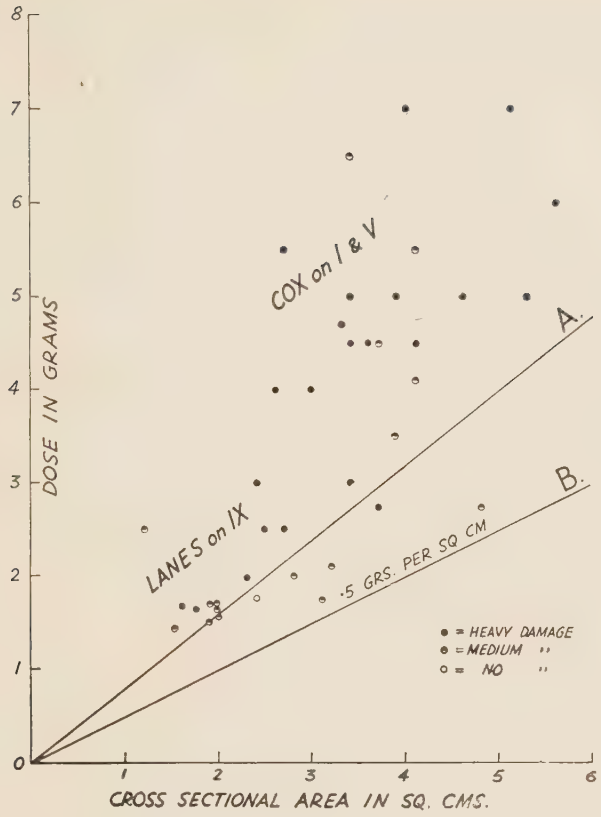


FIG. 2.
Showing the relationship between Dose, Cross Sectional Area and damage, on individual trees—
YOUNG TREES.

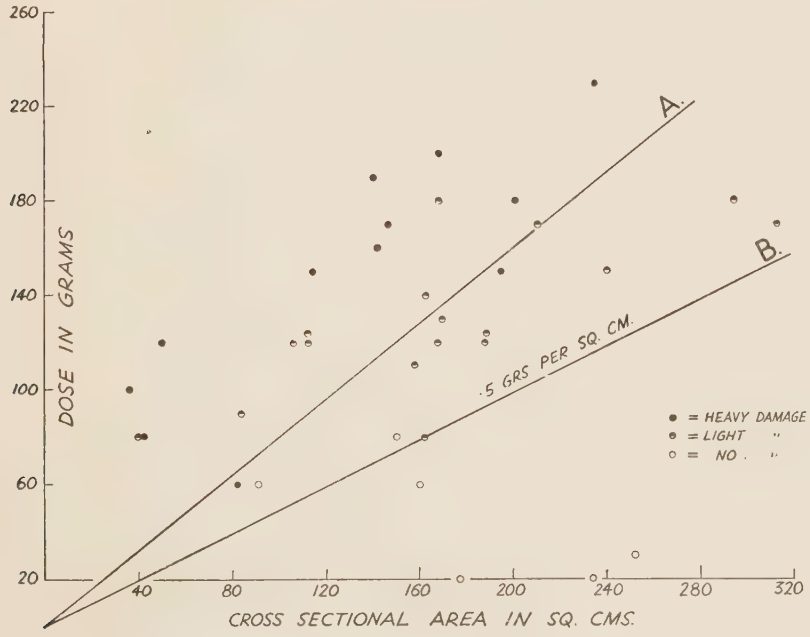


FIG. 3.
Showing the relationship between Dose, Cross Sectional Area and Damage, on individual trees—
MATURE TREES.

above (Comparison 2) and the mature trees of the same variety (Comparison 4), their cross sectional area varying from 2 to 12 sq. cm. No information was available as to what was likely to be the maximum safe dose for them.

The following nutrient solution was used:

| | |
|---|---|
| Potassium phosphate .. | 0·25 gm. |
| Potassium sulphate .. .. | 0·125 gm. |
| Urea .. .. .. .. | 0·125 gm. |
| Water .. .. .. .. | 100 c.c. |

This gave a total concentration of 0·5 per cent.

Although this nutrient was not the same as that used in previous experiments, experience suggested that the dosage would be similar. In this case the total concentration was 0·5 per cent., therefore the maximum safe dose on these trees was estimated at 100 c.c. per sq. cm. of cross sectional area.

To avoid any excessive damage to the trees, a preliminary trial was made on 4 trees. They were given amounts of solution corresponding to 100 c.c. per sq. cm. For example, one tree had a cross sectional area of 10·5 sq. cm. and was given a dose of 1,050 c.c. Absorption on these four trees was completed within six hours. Since after twenty-four hours no leaf scorch had appeared, two of them were given a further 400 c.c. each. A day later these two trees developed scorch, thus showing that this increased dose was too great for them. The remaining two trees had not meanwhile developed any damage.

The rest of the 132 trees were then injected at the rate of 100 c.c. per sq. cm.

This method of dosage was very successful in avoiding damage, as is shown by records of scorch taken a few days after injection (see Table II).

TABLE II.

LEAF SCORCH RESULTING FROM DOSE OF 100 C.C. PER SQ. CM. CROSS SECTION OF STEM.

| Duchess' Favourite Apples. | | |
|---|---|---|
| Scorch. | No. of trees. | Per cent. |
| None .. .. | 87 | 67·9 |
| Slight .. .. | 34 | 26·5 |
| Medium .. | 7 | 5·4 |
| Severe .. .. | 0 | 0 |

Moreover, growth and other responses were also obtained. (See Part III of this Series, p. 107.)

**Discussion.**

The success of this dosage experiment suggests that the method can be used for routine injections. However, the following points must be taken into consideration:

1. Where branches have recently been removed from the tree, the size of the "head" of the tree will be reduced in relation to the cross section of the stem; consequently doses calculated in this manner will be excessive. It has been found satisfactory to estimate by eye the proportion of the dead or missing branch to the rest of the tree and to reduce the dose by that amount. For instance, if a tree that should have received 600 c.c. (according to the cross section of stem) had dead or missing branches amounting to about one-third of the head, then the correct dose will be:

$$600 \times \tfrac{2}{3}, \text{ which is } 400 \text{ c.c.}$$

Further, when a branch has had its leaf area reduced below normal, owing for instance to die-back in the shoots or restriction of growth by a canker, then the dose must again be reduced. With a little experience, the amount by which the dose should be reduced in such instances can be readily judged.

This adjustment of dose was not carried out in the Duchess' Favourite experiment; had it been, the resulting scorch would probably have been even less.

2. It is not suggested that the dose of 0·5 gm. per sq. cm. will be the maximum safe dose for all types of trees in all conditions and with all nutrients; but for the 0·5 per cent. "complete" nutrient on the dwarf bush Duchess' Favourite apple trees in a rather starved condition, it was satisfactory.

On the other hand, the dosage may be affected by several factors. For instance, cordon trained trees do not conform to this formula, and it remains to be seen by further trial how standard or dwarf pyramid types of training affect the issue.

Another factor is the concentration of the solution. Larger amounts of nutrient can be injected with safety in dilute than in concentrated solution.

If the nutrient solution is composed of one or other of the common salts of the major elements, the exact composition should not greatly affect the dosage, although the writer has found that potassium phosphate, for instance, is rather more toxic than urea. Consequently, if a solution contained a high proportion of the former, the dosage would have to be rather less than if the reverse was the case.

If other minerals are used, e.g. iron, manganese, boron etc., the safe dose is only a fraction of that for the major elements.

Recent work by Roberts and Landau (1947) suggests that when using the solid injection method the dose may be rather higher. They found that for potassium sulphate the maximum safe dose was 12 times that recommended by Bennett for iron sulphate, and for potassium phosphate 9 times. According to the graph (Fig. 1), this represents a dose per sq. cm. of approximately 1 gm. and 0·75 gm. respectively, i.e. twice and 1½ times that for liquid injection.

**Conclusions.**

The following procedure can be recommended as a routine method of estimating doses for injecting large numbers of trees.

First, find the maximum safe dose by Roach's method on a few representative trees, and then calculate the dose for the remainder in proportion to their cross sectional areas of stem. It is expected that each set of trees will have its own formula, but that for complete nutrients on bush apple trees is not likely to differ very much from :

½ gm. (total salt) per sq. cm. cross sectional area for solutions of concentrations between 0·5 and 1 per cent.

If circumstances are such that it is not possible to use Roach's method (for instance when trees are being injected in distant plantations) then this formula can be used without previous trial with comparative but not absolute safety.

It will be realized that it is preferable to inject into a tree the optimum rather than the maximum safe dose. But the former has not yet been determined ; it is possible that it too will vary similarly with tree size.

One of the main criticisms of the injection method in the past has been the difficulty of avoiding excessive damage to the trees. It is hoped that this work will help to make liquid injection a reliable and routine method.

**Summary.**

Previous methods for the estimation of dosage and the need for a reliable method are discussed.

Tree size, as measured by the cross sectional area of the stem, is compared with dosage on four sets of trees.

From these it is concluded that the maximum safe dose was approximately 0·5 gm. of salt per sq. cm. of cross sectional area, and that this could be used as a basis for the estimation of dosage in the field.

A trial of this method, on a further set of 132 trees, supported this conclusion.

Recommendations are given for the practical application of the method.

**Acknowledgement.**

The writer is much indebted to Dr. W. A. Roach for valuable help.

References.

Bennett, J. P. (1931). "The treatment of lime-induced chlorosis with iron salts." *Univ. Calif. Agric. Exp. Sta., Circ.* 321.

Roach, W. A. (1938). "Plant injection for diagnostic and curative purposes." *Imp. Bur. Hort. and Plant. Crops, Tech. Commun.* 10.

Roberts, W. O., and Landau, N. (1947). "Multiple Mineral Deficiencies in Fruit Trees." *J. Pomol.*, **23**, 80-91. (In the press.)

# TREE INJECTION II

## METHODS FOR OVERCOMING RESISTANCE TO ABSORPTION OF LIQUIDS

By B. F. G. LEVY

**Introduction.**

The normal method of injecting whole trees with liquid has been to bore one or more holes into the wood of the stem and to rely on the tree to absorb the liquid from the reservoir, through glass and rubber tubes (Roach, 1938). On certain occasions, trees have not absorbed satisfactorily in this manner and Roach has stated: " . . . faulty drilling of holes, especially when temporary clogging results from the use of a blunt bit, seems to have been the commonest cause of failure in the past. Even when holes and cuts are made cleanly, failures to bring about injections are still sometimes encountered."

Roach obtained evidence that injection tends to be slow when either the atmosphere or the soil is moist, and that his usual injection method sometimes fails when both the atmosphere and the soil are in this condition. It has not been found possible to predict when trees will not absorb ; moreover, the fact that trees which are absorbing normally will often be adjacent to non-absorbing trees, shows that the cause of failure is often very local. Such failures are most inconvenient whether in a planned experiment or in a commercial plantation. Some means therefore of modifying the injection method to overcome this difficulty is needed. Several methods were tried out by the writer and are described below.

**Method 1. Using a " Head " of Pressure.**

When a tree refuses to absorb, the natural reaction is to try to force the liquid in. Several methods of applying pressure were tried and the first of these was by the simple procedure of giving a head of pressure to the liquid. This was first applied to a fir tree which would not absorb a dye solution by the normal method. The reservoir containing the dye was slung up on a branch 30 feet above ground and connected by a rubber tube to the injection hole at the base of the tree. Absorption then proceeded satisfactorily and when the tree was felled, it was found that good penetration had been obtained by the dye.

When applying this method to bush apple trees, however, it was found impracticable to raise the reservoir more than 10 feet above ground, when fixed to the head of a vertical pole. Of the trees so injected, the best only absorbed half a litre in a week, while the neighbouring trees were absorbing about 10 litres in two days. This method, although simple, cannot be recommended for bush fruit trees, since the results do not justify the work entailed in fixing a vessel containing a gallon or two of water to the head of a pole and making it sufficiently secure against wind. For trees " on a long leg " the method is practicable and may be suitable, provided that a water-tight join is obtained at the point of injection.

**Method 2. Using a Pressure Pump.**

An alternative method of applying pressure is to use a pump. A convenient apparatus was described by Roach (1938). This was the " Ki-gass " pressure pump, capable of a pressure of about 20 atmospheres and having a slightly tapering nozzle. The trees were bored with a hole of diameter slightly larger than the narrower end of the pump nozzle, the latter could then be pressed a little way into the hole and held in position during the operation, thus giving a watertight joint.

Trials with this pump showed, however, that only a relatively small volume of liquid could be forced into a tree in this manner. In one instance an apple tree, that should have been able to absorb about 20 litres, was treated with this pump ; the most that could be forced in by pumping hard for half an hour, was about 2 litres. After that no more could be forced in without risking splitting the tree (which is easily done with such a pump). Hence this method did not solve the problem, but its trial led to the discovery of a more successful method.

**Method 3. Combined Pumping and Absorbing.**

One tree which had failed to absorb by the normal method of injection was being treated by Method 2. The pump was inserted into the hole which had absorbed no liquid, and between 50 and

100 strokes of the pump were made. It was then observed that the liquid was being sucked through the pump into the tree without further movement of the piston. The tree seemed to have begun to absorb normally. The hole was therefore connected direct to the reservoir in the normal manner, and the tree continued to absorb at a satisfactory rate, eventually taking up the whole of the dose that was originally intended for it. The following field trial was then carried out to test the possibilities of the method.

**Further Trial of Method 3.**

The experimental material consisted of nine mature Bramley's Seedling bush apple trees. They had been injected by the ordinary " whole tree " method, but had not taken up appreciable amounts and, after ten days, absorption had practically ceased. The trees were treated as follows :

*Trees 1 to 5.* In each of these five trees the original injection holes were rebored with a bit an eighth of an inch larger than before and the pump used until absorption had speeded up. (The number of strokes required varied between 50 and 100 from tree to tree.) They were then reconnected to their reservoirs in the normal way. All five finished their dose within two days, absorbing from three to five litres per tree. In one of these trees, the rate of uptake was measured (by the method described below), and when reconnected to the reservoir after pumping, was found to have increased by ten times.

*Tree 6.* In this tree, both holes were rebored as above, but only one hole was pumped. The speed of uptake increased greatly in this latter hole when connected to the reservoir, while the speed of the unpumped hole increased only slightly.

*Tree 7.* Both holes were pumped, but only one was rebored. In the non-rebored hole, the rate was increased a little, but not enough to be of practical importance. In the bored hole, the rate was increased satisfactorily at first, but slowed down again after absorbing 2 litres.

*Tree 8.* Both holes were rebored and pumped. One hole failed to respond. A new hole was bored and pumped and uptake was then satisfactory.

*Tree 9.* Both holes were rebored but neither pumped. This gave a slight improvement, about 1 litre being taken up, but in no way comparable to that obtained in trees 1 to 5.

**A Method for Measuring the Rate of Absorption by Injected Trees.**

The following method has been found of assistance when studying the behaviour of injected trees. It has mostly been used for the " whole tree " method, but can equally well be used with the " branch " method.

The rubber tubing, which connects the injection hole in the tree to its reservoir, was cut at a convenient point, a glass tube, preferably of the same bore as the rubber tubing and about 2 in. in length, was inserted. When the tube was full of solution, an air bubble was introduced into the reservoir end of the glass tube by a quick disconnection and reconnection.

As the solution was absorbed by the tree, the bubble moved quite quickly along the glass tube and the rate of travel was noted. For more accurate measurements, two marks were made on the glass tube a known distance apart (3 cm. has been found convenient) and the time taken for one end of the bubble to travel from one mark to the other measured accurately with a stop-watch. If a standard tube is fitted to all trees, then a direct comparison can be made, one tree with another.

If the actual rate of absorption is required, this can be easily calculated if the bore of the glass tube is known.

Such information is very useful for studying the rate of uptake in varying conditions, and is very convenient in routine injections, as it will allow the size of the containers, and when they are likely to require refilling, to be estimated.

**Discussion.**

The following recommendations can be made as a result of this experiment. With refractory trees, reboring and pumping the original holes will often provide a means of inducing satisfactory absorption.

If this method fails it may be worth while making a fresh hole and pumping that. Probably better results would be obtained from boring fresh holes in every case ; this has the disadvantage of taking longer time than reboring the old hole, it causes more mechanical damage to the tree, and moreover, it is not always easy to find suitable places for the fresh holes. It is therefore advisable to try reboring the old hole first, only making fresh holes should the former method fail.

**Summary.**

It is pointed out that trees will sometimes not absorb liquid when injection is attempted. Three methods of overcoming this are described.

*Method 1* : raising the reservoir to give a head of pressure ;

*Method 2* : using a force pump ;

*Method 3* : using the pump followed by injection in the normal way.

Method 3 is recommended for bush trees.

A method is also described for measuring the rate of absorption during injection.

**Acknowledgement.**

The writer is much indebted to Dr. W. A. Roach for valuable help.

## References.

Roach, W. A. (1938). " Plant injection for diagnostic and curative purposes." *Imp. Bur. of Hort. and Plant. Crops, Tech. Commun.* 10.

# TREE INJECTION III

## RE-INVIGORATION OF DEBILITATED TREES

By B. F. G. LEVY

**Introduction.**

Although potash deficiency symptoms in apples may appear in severe cases in May or June, frequently they are not brought to the notice of the Advisory Officer until June or July. A heavy dressing of potash is the normal remedy, but even if it were applied immediately, it would hardly have any effect for at least a year, and in this time the condition of badly affected trees might have become hopeless. Injection of nutrients in midsummer seemed worth trying as a possible means of preventing the condition worsening unduly until ground dressings could take effect.

The following experiment was carried out in July, 1937, on trees which formed the guard rows of a manurial trial which has been described by Hoblyn (1940). These trees were of the variety Duchess' Favourite and were growing on plots that had received no potash for ten years. There were four non-potash plots (Nil, N, P, NP) on each of eight blocks, and as there were eight trees per plot there were 256 in all. In the tables which follow, the figures are arranged in four columns corresponding with the four soil treatments, and in general they can be considered as replicates ; but for leaf scorch due to potash deficiency, the soil treatment has modified the effect of injection.

These Duchess' Favourite trees were 6-year-old dwarf bushes on rootstock M. IX and were in a very debilitated condition. Much leaf scorch was present and many shoots were dying back into the old wood. The few current year's shoots present had stopped growing by July, and the blossoms had shown symptoms described as " Ghost Blossoms " (Hoblyn, 1940, and Rogers, 1944).

**Injection.**

Alternate trees round the plot were injected, thus giving four treated and four control trees per plot, or 128 treated and 128 controls in all.

The nutrient solution injected was of the following percentage composition :

| | |
|---|---|
| Urea .. .. .. .. .. | 0·125 per cent. |
| Potassium sulphate .. .. .. | 0·125 per cent. |
| Potassium di-hydrogen phosphate .. | 0·25 per cent. |
| Giving a total salt concentration of .. | 0·5 per cent. |

This " complete " nutrient with a relatively large proportion of potash was chosen because the main cause of the debility seemed likely to be due to potassium deficiency, but a general lack of nutrients was also a possibility owing to the poor condition of the soil.

The method of injection adopted was the " branch " method as described by Roach (1938) and Levy (1939) using waxed carton containers and rubber and glass tubing. The dose for each tree was calculated from its girth measurement, as described elsewhere. (See p. 99 of this Report.)

A trial injection was begun on 14th July, 1937, on four trees. Since no undue damage occurred after two days, it was assumed that this method of estimation was reliable, and injection of the bulk of the trees was commenced on 16th July and finished by 28th July.

**Records.**

The following records and observations were made during the current and following season.

| | *Record.* | *Date of Record.* | |
|---|---|---|---|
| | | *Pre-injection* | *Post-injection.* |
| 1. | Leaf scorch due to injection .. .. | — | July, 1937. |
| 2. | Leaf scorch due to potash deficiency | August, 1937. | August, 1938. |
| 3. | Amount of die-back .. .. .. | March, 1938. | August, 1938. |
| 4. | Amount of " ghost blossoms " .. | May, 1937. | May, 1938. |
| 5. | Number of growing shoots .. .. | July, 1937. | August, 1938. |
| 6. | Proportion of wood buds to blossom | — | May, 1938. |
| 7. | Wood growth measurements .. | March, 1938. | March, 1939. |
| 8. | Crop weights and numbers .. | — | August, 1937, and August, 1938. |

**Results.**

The results of injection as indicated by these records are detailed below under their respective headings.

1. **Leaf scorch due to injection.** This type of scorching occurs on mature leaves when an overdose is given, with the result that the edges of some leaves seem to be plasmolysed and are killed (Roach, 1938). The edges so affected soon become obvious by their brown and dry appearance. For some days this brown colour is of a lighter and redder shade and the leaves less brittle than with the scorch due to potassium deficiency, but later the two conditions are hardly distinguishable.

The records were made from 2 to 3 days after injection, beyond which time the amount of scorch did not materially increase. According to these observations each tree was graded into one of five categories and the number of trees in each category was as follows :—

| | |
|---|---|
| No scorch .. .. .. | 53 |
| Trace scorch .. .. .. | 34 |
| Light scorch .. .. .. | 34 |
| Medium or heavy scorch .. | 7 |

Periodic observations revealed that only a few shoots had been killed by the injections.

2. **Leaf scorch due to potash deficiency.** This scorch was typical of the well-known symptom of potash deficiency, which is described by Hoblyn (1940), and was recorded by giving to each tree a figure which represented the percentage of the leaves on the tree that were affected, e.g. " 1 "—10 per cent. scorched ; " 2 "—20 per cent. scorched, and so on. From these tree figures the means were obtained for each treatment.

The records for 1937 were made in August and represented the symptoms that had appeared in June, that is, before the trees had been injected. Their purpose was to obtain an indication of the uniformity of the trees and for comparison with the next year's records.

Unfortunately the only valid figures for 1937 were those taken on block VII and half of block V by the writer ; on the remaining blocks, potash scorch symptoms were confused with those caused by injection damage, thus giving too high a figure for the injected trees.

The figures for block VII were :

| | |
|---|---|
| Mean for injected trees .. | 2·2 |
| Mean for control trees .. | 2·1 |

showing that, at least in this block, the trees chosen to be injected had the same amount of scorch as the controls.

The records for 1938 were also made in August, nearly one year after injection ; this time there was no injection scorch for confusion. The mean figures for each treatment are given in Table I. The totals from this table show that the mean figure was 10 per cent. less on the injected trees than on the controls : 3·5 to 3·9. But it will be seen that this effect is mostly confined to the NIL and N plots, where there was a 20 per cent. reduction ; while on the P and NP plots there was only a 4 per cent. reduction.

These figures when analysed statistically show that the differences on the NIL and N plots together are very significant (over 1 in 1,000), while those on the phosphate plots are not significant ; the interaction between the effects of phosphate and injection is also significant (over 1 in 20).

TABLE I.

POTASH DEFICIENCY SCORCH RECORDS.

MEAN TREE FIGURE FOR EACH TREATMENT.

**1938 : After injection.**

| | Soil treatment. | | | | |
|---|---|---|---|---|---|
| | Nil. | N. | P. | NP. | Total. |
| Control .. | 4·1 | 3·8 | 3·75 | 4·0 | 3·91 |
| Injected .. | 3·6 | 3·0 | 3·6 | 3·9 | 3·52 |

Thus in the absence of phosphate there was a clear cut reduction of leaf scorch on the injected trees, and this reduction seems to be sufficiently large to be of economic importance. But in the presence of phosphate the reduction was inconsiderable.

These decreases, moreover, had taken place in spite of the fact that the severity of leaf scorch seemed to have increased on these trees since 1937 ; for instance in block VII (the only block with comparable figures for the two years), the mean figure (injected and control together) for 1937 was 2·1, and for 1938 was 3·1.

### 3. Die-back.

The incidence of die-back was recorded in March, 1938, when the trees were pruned. Die-back had occurred on about a quarter of the trees and the extent on each tree was recorded by measuring the total length of dead wood in cm. This represented the amount of wood that had died in early summer of 1937, before injection had been carried out. Each tree was allocated to one of four die-back classes.

A summary of the number of affected trees on each plot is shown in Table IIA. The totals show that 30 of the injected trees were affected and 27 of the controls. The mean tree figure derived from the die-back class is 1·8 injected and 1·7 control.

It is clear from these data that before the trees were injected the amount of die-back was equally distributed over both sets of trees.

Fresh die-back had occurred by June, 1938, and was recorded in that month by estimating the percentage of each tree that was affected and allocating it to a die-back class accordingly. The total number of trees affected is shown in Table IIB in which it will be seen that whereas 42 (33 per cent.) of the controls showed die-back only 5 (4 per cent.) of the trees injected in July, 1937, were affected. If these numbers are expressed as a percentage of the 1937 numbers, the following figures are obtained : control 156 per cent., injected 16·7 per cent.

The mean tree figures derived from the die-back class numbers are : control 2·2, injected 0·2.

TABLE II.

DIE-BACK RECORDS.

SUMMARY OF NUMBER OF AFFECTED TREES.

**A. Before injection.**

| | Soil treatment. | | | | |
|---|---|---|---|---|---|
| | Nil. | N. | P. | NP. | Total. |
| Control .. | 9 | 5 | 8 | 5 | 27 |
| Injected .. | 9 | 8 | 10 | 3 | 30 |

**B. After injection.**

| | | | | | |
|---|---|---|---|---|---|
| Control .. | 13 | 11 | 8 | 10 | 42 |
| Injected .. | 1 | 2 | 2 | 0 | 5 |

Thus the die-back was considerably reduced on the injected trees, whereas on the controls the incidence had increased since the previous year.

Plate I shows a typical pair of trees in June, 1938. On the control (A) most of the leaders bore only dead leaves and were themselves dead or dying ; while on the injected tree (B) the leaders were fully furnished with live leaves and no die-back could be seen.

### 4. "Ghost blossom."

In May, both in 1937 and 1938, the numbers of trees affected with ghost blossoms were noted and each tree was placed into one of four classes according to the percentage of the blossoms affected. In 1937 slightly less than half the trees were affected (61 trees later injected and 55 controls), as shown in the summary in Table IIIA. Thus the two sets of trees were equally affected before injection.

The summary for 1938 is given in Table IIIB. Owing to the fact that several of the injected trees bore no blossoms at all in this year, a fairer comparison with the controls is obtained by expressing the total number of affected trees as a percentage of the number of trees bearing blossom. These figures are shown in the column marked %. From these it is evident that there was a considerable reduction in the number of injected trees with " ghost blossoms " in 1938 as compared with the controls.

This result is also borne out by the figures derived from the distribution into classes. The mean class figures were :

| | | | | |
|---|---|---|---|---|
| for 1937 : | control | 1·9 | injected | 1·9 |
| and for 1938 : | control | 1·2 | injected | 0·1 |

TABLE III.

GHOST BLOSSOM RECORDS.

SUMMARY OF NUMBER OF AFFECTED TREES.

**A. 1937 : Before injection.**

| | Soil treatment. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Nil. | | N. | | P. | | NP. | | Total. | |
| | No. | % | No. | % | No. | % | No. | % | No. | % |
| Control .. .. | 17 | 53 | 12 | 37 | 17 | 53 | 9 | 28 | 55 | 44 |
| Injected .. | 14 | 44 | 15 | 47 | 20 | 62 | 12 | 37 | 61 | 48 |

**B. 1938 : After injection.**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Control .. .. | 13 | 42 | 6 | 20 | 5 | 16 | 12 | 37 | 36 | 29 |
| Injected .. | 2 | 9 | 2 | 8 | 2 | 7 | 2 | 7 | 8 | 8 |

## 5. Shoot Growth Analysis.

Analysis of the types of current year shoots present on individual trees was made according to the method described by Vyvyan (1935). This was done some days after injection, but before the injection had had time to cause any appreciable effect, because only shoots or rosettes with *fully* open leaves were recorded as such. Both long and short shoots were considered together.

Two blocks were recorded thus and showed that the injected trees bore 1½ times as many growing shoots as the controls *before* injection, i.e. control 23, injected 34.

A month later, as shown in Table IV, the treated trees on the whole Plot bore 12½ times as many growing shoots as the controls.

TABLE IV.

CURRENT YEAR SHOOT RECORDS.

SUMMARY OF NUMBER OF GROWING SHOOTS.

**After injection.**

(Injected 16-28.7.37, Recorded 30.8.37.)

| | Nil. | N. | P. | NP. | Total. |
|---|---|---|---|---|---|
| Control .. .. | 14 | 3 | 8 | 7 | 32 |
| Injected .. .. | 142 | 98 | 83 | 80 | 403 |

The appearance of these new growing shoots can be seen on the tree illustrated in Plate IIb, as compared with its neighbouring control (Plate IIa) on which there were no new shoots.

Thus the injected trees had produced more new growing shoots at the end of August than is normal. On this plot, the trees usually had practically stopped growing by August ; this was shown by comparing the control trees of blocks V and VII in July and August, where the number of growing shoots decreased from 23 to 2. On the other hand the injected trees increased from 34 to 56.

Thus, although the injected trees had 1½ times more growing shoots than the controls before injection, there is no doubt that the increases after injection were far more marked, and quite unrelated to the initial difference.

## 6. Bud records.

By the spring of 1938, a striking difference could be seen between the injected and control trees, in that the former seemed to have far fewer fruit buds and more wood buds on each tree. A summary of the total numbers of wood and fruit buds is given in Table V. The fruit buds are expressed as a percentage of the total buds on the tree. This shows a clear difference between injected and control trees, the former having 23 per cent. fruit buds and the latter 42 per cent.

When the individual tree records were compared with those for summer growing shoots it was seen that those trees that had most growing shoots in summer 1937 had the lowest percentage of fruit buds in 1938.

This confirms what was suspected in 1937, namely, that these shoots had arisen from buds which, they they not been stimulated into growth, would have formed fruit buds, and satisfactorily explains the lack of blossoms on the injected trees in 1938.

TABLE V.

BUD RECORDS.

SUMMARY OF NUMBER OF FRUIT AND WOOD BUDS.

**1938 : After injection.**

| | Soil treatment. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Nil. | | N. | | P. | | NP. | | Total. | |
| | Con. | Inj. | Con. | Inj. | Con. | Inj. | Con. | Inj. | Con. | Inj. |
| Fruit .. .. | 2,898 | 1,119 | 2,948 | 1,756 | 1,674 | 1,275 | 2,523 | 1,133 | 10,043 | 5,303 |
| Wood .. .. | 3,171 | 5,045 | 3,703 | 4,388 | 3,710 | 4,423 | 3,001 | 4,513 | 13,782 | 18,171 |
| Total Buds .. | 6,069 | 6,164 | 6,651 | 6,144 | 5,348 | 5,698 | 5,524 | 5,646 | 23,825 | 23,474 |
| Fruit % .. | 48 | 18·2 | 44 | 29 | 31 | 22 | 46 | 20 | 42 | 23 |

## 7. Wood growth.

The amount of wood growth made in 1937 and 1938 was measured on each tree. In 1937 there was not much extension growth and the records show considerable tree to tree variations ; for instance, the tree totals for the first two plots varied as follows :

| | C. | Inj. | | C. | Inj. |
|---|---|---|---|---|---|
| Plot A4 | 0 | 0 | Plot A2 | 0 | 44 |
| | 19 | 188 | | 15 | 0 |
| | 36 | 6 | | 44 | 5 |
| | 156 | 153 | | 45 | 0 |
| | 211 | 347 | | 104 | 49 |

In 1938 there was considerably more growth per tree, but again much variation from tree to tree.

In these records only those shoots over 5 cm. long were measured. With dwarf trees such as these, however, the majority of shoots are either just under or just over 5 cm., so that this rather arbitrary limiting figure was unsuitable for the present purpose.

## 8. Crop.

The crop of 1937 was fairly heavy. The number of fruits and weight for each tree were recorded at each picking. No difference was found between injected trees and controls in total number of fruit, total weight, average weight per fruit or in time of ripening.

The crop in 1938 was very light and very variable from tree to tree, so that no deductions can be drawn.

## Discussion.

The most important result of the experiment economically was the reduction of die-back ; this enabled many trees to keep their main framework until the ground treatments could be effective,

whereas many of the untreated trees were maimed by the removal of branches as a result of this die-back.

The most marked result was the effect of injection on the production of growing shoots. It was suggested that this might have been brought about by the damage done to the leaves by injection scorch. In other experiments damage to leaves, especially where defoliation has occurred as well, has been followed by a stimulation of non-growing buds into growth. A comparison was made of those trees that bore more or less shoots, with those that received more or less injection scorch ; no correlation between the two factors could be found. It was unlikely that new growth could have been stimulated to such an extent by injection damage unless it was particularly severe ; in this case the damage was light compared with some other experiments.

However, as these new shoots stopped growing quickly the main point of practical importance was the fact that the number of fruit buds for 1938 was reduced, since it was mostly incipient fruit buds that were brought into growth.

The effect of injection on the incidence of " ghost blossoms " is of some interest. It had been known that they were closely connected with die-back, but it had also been considered that they were dependent on poor soil conditions. The fact that an injection of a complete nutrient with large proportion of potash has reduced its incidence, does suggest that it is more a direct nutritional problem, concerning potash in particular.

**Conclusions.**

The experiment does not allow of any final conclusions, but it does show that benefit can be derived from injections in midsummer in spite of the fact that growth had practically ceased. The amount of deterioration was reduced, but neither the cropping nor the extension growth was materially increased in the year in which the injection was done or the next. However, the injected trees by the summer of 1938 seemed likely to produce better growth and crops the next year since they possessed more bearing wood and healthier leaves.

**Summary.**

Duchess' Favourite apple trees severely affected by potassium deficiency were injected in midsummer with a " complete " nutrient rich in potassium.

In the same summer, incipient fruit buds were stimulated into vegetative growth.

In the next spring, on the treated trees there were decreases in the proportion of fruit to wood buds, in die-back, in " ghost-blossoms ", and later in leaf scorch. No increases in extension growth or cropping were detectable.

It is concluded that benefit can be derived from midsummer injections for potash starved trees.

**Acknowledgement.**

The writer is much indebted to Dr. W. A. Roach for valuable help.

References.

Hoblyn, T. N. (1940). " Manurial Trials with Apple Trees at East Malling, 1920-39. B. Trials with Cox's Orange Pippin and Beauty of Bath." *J. Pomol.*, **18**, 330-43.

Levy, B. F. G. (1939). " Plant injection for the diagnosis of mineral deficiencies." *Rep. E. Malling Res. Sta. for 1938*, 235-43.

Roach, W. A. (1938). " Plant Injection for diagnostic and curative purposes." *Imp. Bur. Hort. and Plant. Crops, Tech. Commun.* 10, (p. 41).

Rogers, W. S. (1944). " Orchard soil management." *Rep. E. Malling Res. Sta. for 1943*, 85-7.

Vyvyan, M. C. (1935). " The leaf relations of fruit trees. II. The census method for recording summer growth." *J. Pomol.*, **13**, 202-19.

A. Control.

B. Injected.

PLATE I. Die-back.

[face p. 112

A. Control.

PLATE II. Shoot growth.

B. Injected.
Note new shoots in top half of tree.

## PLANT PATHOLOGY

# A REVIEW OF SOME RECENT RESEARCH ON VIRUS DISEASES OF RASPBERRY AND STRAWBERRY IN GREAT BRITAIN*

By R. V. HARRIS

The virus diseases of raspberry and strawberry, which form part of the research field in fruit plant pathology at East Malling and at University College, Dundee,† are of the highest importance to fruit culture, both in Scotland and in the United Kingdom generally, where raspberries and strawberries flourish prolifically as wildings in woodland and hedgerow and are extensively cultivated commercially and in private gardens. Thus, in Scotland, raspberry and strawberry growing on a commercial scale has been practised increasingly for the last fifty years and, in 1945, some 5,000 of the total 6,700 fruit acres returned by the Department of Agriculture were under these crops (4,000 acres of raspberry plantations, mainly concentrated in Angus, South-East Perthshire and Fife, and 850 strawberry acres divided between the Clyde Valley and the South-Eastern districts). These figures, however, must not be taken to indicate anything like a steadily maintained progress in these industries. On the contrary (and in interesting contrast to the ever flourishing wilding communities) both these industries have been periodically faced with crises of declining productivity which have virtually threatened the principal producing areas with extinction.

Such a crisis in the strawberry industry occurred during the years immediately following the first world war, when widespread degeneracy of current stocks of our own Royal Sovereign, Sir Joseph Paxton and other high grade strawberry varieties led to their gradual replacement by inferior ones from abroad, such as Madam Kooi, Madam Lefebvre, Oberschlesien and, in later years, Huxley's Giant. In the Clyde Valley this trend to varietal degeneracy was temporarily obscured and overshadowed at this time by the devastations of the Lanarkshire Disease (of fungus origin), now generally known as Strawberry Red Core Root Rot, but it was none the less present and has recently returned to prominence with the control of Red Core brought about by the introduction of Mr. R. D. Reid's Red Core Resistant " Auchincruive Seedlings ".

At the same time, in the concentrated raspberry district of South-East Scotland, the once prolific Antwerp, Baumforth's Seedling, and Mitchell's Seedling varieties were generally failing, later to be replaced, almost universally, during the late twenties by the newly-introduced and exceptionally vigorous Lloyd George raspberry. The rise, complete dominance and present decline of Lloyd George accurately defines the succeeding raspberry epoch in Scotland as in England. This epoch reached its peak about 1937, when 6,000 acres in South-Eastern Scotland produced 10,000 tons of fruit, and has since drastically declined until the acreage in the same district had fallen to 4,000 in 1944, with a corresponding decrease in productivity from an average of 2-3 tons to a paltry 15 cwt. per acre. This waxing and waning of our soft-fruit industries is now known to be principally due to a progressive infiltration of each leading commercial variety by potent virus diseases, brought about by indiscriminate uncontrolled vegetative propagation.

### I. The Spread of Virus Diseases by Vegetative Propagation.

Both the cultivated strawberry and raspberry are perennial plants which do not breed true from seed. To meet the demands of plantation economy and for uniform fruit quality, each plantation is planted with a selected horticultural variety which is the product of an indefinitely prolonged vegetative division of a single seedling individual. Both crops readily propagate themselves in this way, by " Runners " and " Sucker canes " respectively. A single strawberry plant may thus produce as many as 200 runner progeny in a single season, and a raspberry plant up to 20 or 30 rooted canes. The maintenance of such ideal uniformity in performance, however, presupposes that the variety remains (1) genetically stable, or approximately true to type and uncontaminated with seedling " Rogues " ; and (2) free from infection by such diseases as virus diseases. Assume even a very slow rate of insect borne infection by a virus disease which (*a*) permeates the complete plant system,

* A lecture delivered to the Royal Philosophical Society of Glasgow on 27th November, 1946, and reprinted from the Proceedings of the Society by kind permission.

† Agricultural Research Council Scottish Raspberry Investigation, conducted by East Malling Research Station.

(*b*) induces degeneration rather than death and (*c*) cannot be eradicated by direct means, and *uncontrolled* vegetative propagation will do the rest ; that is, each of the 200 runners from an infected strawberry plant will become infected and will constitute a new centre of natural infection in the new plantation, and so on until all existing sources of that variety are totally infected with virus.

## II. The Diseases and their Transmission.

Between 1927 and 1942 four major virus diseases (or disease groups) were identified and distinguished by their symptoms in this country, namely, the Yellow-edge and Crinkle diseases of strawberry (Harris, 1933*a* ; Ogilvie *et al.*, 1934), and Mosaic Disease and Leaf Curl (in Scotland) of raspberry (Harris, 1933*b* ; Harris *et al.*, 1943). These diseases proved to be graft-transmissible to normal plants (a distinguishing feature of virus diseases) and, having been thus introduced, each disease was observed to permeate rapidly the entire plant system to the ultimate runner or sucker-cane.

Massee (1935, 1943) later showed that the two strawberry diseases were transmitted in nature by the common strawberry aphid, *Capitophorus fragariae* Theob., and from subsequent work with strawberry insects it seems probable that this aphid is the sole natural vector of strawberry viruses. Parallel attempts to transmit the raspberry diseases by insects culminated in the present year when C. H. Cadman and A. R. Hill, working at Dundee, obtained transmissions of two types of mosaic disease by the two common raspberry aphids *Amphorophora rubi* Kalt and *Aphis idaei* V. der G., respectively (unpublished work). We can therefore, now, fairly safely assume that the principal virus diseases of both strawberry and raspberry are insect borne.

Compared with the virus diseases of many annual crops all these soft fruit diseases spread relatively slowly under natural plantation conditions, the raspberry diseases having the lower rate of spread With the possible exception of Leaf Curl in Scotland on certain varieties, all these diseases induce degeneration rather than the death of their host plants.

Regarding the persistence of the diseases in the infected plant, attempts have been made to inactivate the strawberry viruses by heat treatment of infected runners without any results to date. Although the expression of certain of the strawberry and raspberry diseases fluctuates with changes in the plant environment, no instance of complete natural recovery has yet been observed. The viruses appear to persist until the death of their hosts.

Finally, all attempts to transmit the diseases to normal plants mechanically by inoculations with expressed sap have also failed, for the probable reason, as the Rothamsted workers have recently shown, that all proteins, including any viruses present, are immediately precipitated in extracted strawberry and raspberry sap by a copious release of tannin (Bawden and Kleczkowski, 1945).

To sum up the foregoing information, we can now describe our four major diseases of strawberry and raspberry as relatively slow-spreading degeneration diseases caused by ultra-microscopic graft-transmissible systemically distributed viruses or virus-complexes, some of which at least are insect borne, and which cannot be eradicated from an infected plant by direct means (are incurable) or isolated in active condition. It will be appreciated, of course, that any of the above generalizations is subject to particular revision in the light of further research.

## III. Methods for Analysing the Virus Complexes.

As many virus diseases are caused by more than one virus (virus complexes) and different viruses may induce similar symptoms on the same host plant, the next stage in research was to identify and relate the viruses and virus complexes responsible for the major diseases or symptom types already described. As these viruses are ultra-microscopic and, as we have seen, could not be isolated and identified outside their living host plants, the sole remaining basis for their identification was the symptoms (or clinical picture) produced on transferring them to a selected range of comparatively normal " Indicator " plants by grafting or by insect vectors.

*Transmission by grafting*, when used for this purpose has the limitation of being rarely, if at all, selective, all the viruses present in the diseased component passing over the graft union into the Indicator plant. Virus complexes or associations cannot therefore be split up into simpler components by this means, nor the diseases interpreted in terms of individual viruses. Grafting, however, unlike the insect vector, is a certain method of transmission for every virus, for a positive union implies that, whatever the Indicator subsequently shows or does not show, all the viruses have passed into it. In this way it was early found that horticultural varieties of raspberry and of strawberry differ greatly among themselves in their reaction to these virus diseases, both as regards sensitivity or tolerance and, more particularly in the case of raspberries, in the symptom-picture produced. Varieties were found to range from virtually symptomless-carriers (or " Tolerants ") to highly expressive " Sensitives ".

*Transmission by insect vectors*, however, may be selective, involving as it does special relations between the viruses and their temporary animal hosts. Most plant virus infection is due to insect agency, and that mainly by aphides which feed by inserting delicate stylets intercellularly and sucking

the plant juices. Fortunately such insect borne infection is neither purely mechanical nor an inevitable result of feeding by any insect previously contaminated by contact with an infected plant. Thus, as we have seen, the strawberry aphis vector can transmit virus-diseases which cannot be transmitted by sap inoculation or by other insects feeding on the strawberry plant. Even to achieve a successful transmission with the correct insect vector certain conditions must be fulfilled, and these conditions may differ with the virus to be transmitted. Recent conclusions of the Rothamsted workers in this field have provided a ready method for the separation of such commonly associated viruses as the " Y " and Leaf roll viruses of potato, and the Yellows and Mosaic viruses of sugar beet. To quote F. C. Bawden (1946, p. 144) : " Two contrasting types of relationship have been distinguished between different viruses and their insect vectors. Vectors of one type of virus can infect a healthy plant immediately after they have fed on a diseased plant, and such vectors usually cease to be infective within a short time, usually within a few hours of leaving the infected plant. Vectors of the second type cannot infect healthy plants immediately after they have fed on a diseased plant ; there is a delay in the development of infectivity, sometimes called an incubation period, which with different viruses varies from hours to days. Once such vectors have become infective they remain so for long periods." Without discussing the why and wherefore of these differing virus-to-vector reactions it must be obvious that by adjusting the times of feeding on the source of the virus inoculum, and the interval of subsequent transfers to Indicators, insect vectors can be utilized for the separation of the viruses constituting a complex association. This method has now been successfully used by T. Whitehead and C. A. Wood at University College, Bangor (unpublished), and at East Malling (Prentice and Harris, 1946) for the resolution of strawberry virus complexes by the aphid vector *Capitophorus fragariae*. Its more recent application by Cadman and Hill at Dundee to the determination of the raspberry virus vectors led to the positive results of the 1945-6 experiments. Let us now briefly review the progress made in the analysis of the virus diseases of each of our crops by the combined use of grafting and of differential aphid transmission.

**IV. Strawberry Virus Analysis.**

The Yellow-edge and Crinkle symptom groups were identified and described by grafting diseased plants to Indicators consisting of individuals of a clone (or sub-race) of the Royal Sovereign variety selected for its apparent freedom from any obvious symptoms. No cultivated strawberry variety has yet been found with a sensitivity to Yellow-edge and Crinkle exceeding that of Royal Sovereign. Many varieties, however, were found to be less sensitive, such as the now commonly grown Huxley's Giant, and *apparently* virus free plants of such varieties (" Tolerants ") on grafting to Royal Sovereign Indicators not infrequently induced severe symptoms of Yellow-edge on the latter. Plants of such Tolerants were occasionally observed to express symptoms of Yellow-edge with considerable signs of degeneration. Such an apparent " break-down " of tolerance might imply an alteration, either in host-tolerance, or of the virus or virus-complex by mutation or by the addition of another virus or viruses, and recent experiments at East Malling have confirmed the latter explanation (Prentice *et al.*, 1946). The only approximation to sustained and complete tolerance to all viruses so far discovered is a strain of the parent species of the European cultivated strawberry hybrid *Fragaria chiloensis* (the American " Beach Strawberry "). In passing it may be mentioned that the expression of symptoms even on the sensitive Royal Sovereign fluctuates with varying seasonal conditions, and some research has been done to determine the critical conditions for full field expression of Yellow-edge on this and like varieties (King and Harris, 1942). This obviously has an important bearing on the field selection of healthy stocks.

Whether Yellow-edge and Crinkle are caused by single or complex viruses and whether they are related (have viruses in common) was the subject of later analytical work which started with the discovery (Harris and King, 1942) of a mild virus in the apparently symptom-free clone of Royal Sovereign already referred to, by the use of symptomless plants of the common woodland strawberry (*F. vesca*) as an Indicator. These plants when grafted to the apparently virus-free Royal Sovereign developed a blistering, speckling leaf symptom. On further examination of the Royal Sovereign plants minute spot-lesions were found inconspicuously and sparsely grouped towards the bases of some of the leaves, and these were seen to be qualitatively similar to the spot-lesions of Severe Crinkle. This disease (virtually *carried* by Royal Sovereign) was called Mild Crinkle and its virological relationship to Severe Crinkle and Yellow-edge had then to be determined. Although Yellow-edge-free plants with Mild Crinkle were common (the clone referred to proved to be totally infected with Mild Crinkle) no Yellow-edge plants were ever subsequently found to be entirely free from Mild Crinkle lesions. This might simply imply chance association, or that Mild Crinkle virus is a component of Yellow-edge. In all subsequent work the highly-sensitive *F. vesca* has been used as a routine Indicator in conjunction with Royal Sovereign. Analytical work was further facilitated by the discovery in West Ireland of an entirely symptomless source of Royal Sovereign, which gave no virus

reaction when grafted to *F. vesca* and therefore proved to be free from Yellow-edge, Crinkle and Mild Crinkle.

Further analysis by the combined use of grafting and the aphid vector was started in 1942 at Bangor and East Malling and by this method three viruses or virus complexes have now been distinguished on *F. vesca* and Royal Sovereign indicators (Prentice, 1946). One of these (Virus 1) appears to be the cause of the original Mild Crinkle *carried* by Royal Sovereign and is picked up by the aphid vectors on a relatively short feeding period. It does not generally persist in the aphid for more than three hours. In contrast, virus 2 and virus 3 are relatively long persistent in the vector. They are picked up only on a prolonged feed on Yellow-edge and Severe Crinkle plants respectively and are re-transmitted (without admixture with virus 1) to the second and subsequent *F. vesca* indicators in successive daily transfers. Virus 2 by itself on Royal Sovereign causes faint hardly detectable symptoms of the the Yellow-edge type. Virus 3 by itself causes moderately severe Crinkle symptoms. Combine (by grafting) virus 2 (mild Yellow-edge) with virus 1 and severe (or field) Yellow-edge results. Combine virus 2 (mild Yellow-edge) with virus 3 (severe Crinkle) and the severest Yellow-edge results. Combine virus 3 (severe Crinkle) with virus 1 and the severest Crinkle results.

We conclude broadly from this analysis at its present stage that there are at least two distinct severe Yellow-edge diseases, each caused by not less than two viruses one of which, the persistent Yellow-edge virus, is common to both ; also that Mild and Severe Crinkle are distinct and unrelated diseases, the virus of the former having short, and that of the latter long, persistence in the aphid vector ; and finally that these Crinkle viruses also function as constituents of the two Yellow-edge diseases, Crinkle thus being shown to be related to, and included in, Yellow-edge.

**V. Raspberry Virus Analysis.**

Advance in analytical progress has been slower with raspberry owing to the much greater complexity of the symptom groups, and to the lack, up to this year, of positive information on insect vectors.

With strawberry, variation in the symptom expression of Yellow-edge and Crinkle by different varieties is essentially quantitative. That is, *if* yellow-edge shows on a variety (even on a relatively tolerant variety) the clinical picture is recognizably Yellow-edge as shown by Royal Sovereign indicators, and the same applies to Crinkle.

With raspberry, however, the variation is not only quantitative but frequently qualitative ; a disease with one type of symptom if graft transmitted to another variety frequently induces noticeably different symptoms on that variety.

Prior to 1942, raspberry Mosaic Disease was subdivided into two symptom categories sharply distinguished on the only indicator employed up to that time, the highly virus-sensitive Scottish variety Baumforth's Seedling B, and these were provisionally named Mosaic 1 and Mosaic 2 (Harris, 1940). In combination they could still be visually distinguished. Reciprocal graft-transmission, however, indicated that the Lloyd George variety did not express Mosaic 2 by any distinguishable leaf symptom and, moreover, samples of this variety from which all canes with mosaic symptoms had been eliminated, or " rogued ", were found, when grafted to Baumforth's B indicators, to be widely "carrying" Mosaic 2. Mosaic 1 on the other hand was visually expressed by Lloyd George with typical symptoms, but when the two " diseases " were combined, intensified mosaic symptoms were induced which differed from both parent types and were referred to as common " Lloyd George Mosaic ". Lloyd George raspberry is referred to as a " carrier " of Mosaic 2, but this is not strictly correct. For although no diagnostic leaf symptoms are expressed the general vitality of the variety is adversely affected though not severely. This applies in greater degree also to those other, and so far unidentified, raspberry viruses which augment the process of degeneration without inducing any distinct diagnostic symptoms, and is another point of difference between the strawberry and raspberry diseases, for measurable degeneration in the former is generally accompanied by visual leaf symptoms.

By the time the raspberry analysis had reached this stage the great majority of Lloyd George stocks in the British Isles were already degenerate. One or two selections, however, meticulously " rogued " for all visible virus diseases, and propagated from 1931 in isolation of some miles from commercial raspberry plantations, have maintained exceptional vigour up to the present time. One of these stocks propagated by Mr. Arthur Amos of Wye, Kent (now known as the " Amos Lloyd George ") on testing to Baumforth's B indicators some years ago was found to be widely infected with Mosaic 2. A proportion of the indicators, however, developed inconspicuous curling symptoms (distinct from Leaf Curl in Scotland) without any mosaic mottling, but, on transfer to symptomless Norfolk Giant, a distinct vein-clearing symptom of the Mosaic 1 type was produced (unpublished work). Combined with Mosaic 2 this " Curly Dwarf " produced a very intense Mosaic 2 symptom in both

the Norfolk Giant and Baumforth's B indicators followed by rapid death. It was concluded that even the best extant local strains of Lloyd George were prevalently infected with at least two potent viruses or virus groups. It further follows that each of the Mosaic 1 and Mosaic 2 categories is a complex association of viruses and there is also evidence that, over and beyond the " Mosaic 2 plus Curly Dwarf " level of Lloyd George infection, there are other non-expressing and as yet unidentified viruses which are responsible for the latter stages of that drastic degeneration which characterizes the majority of field stocks of this variety in Scotland and elsewhere to-day.

In addition to the Mosaic diseases must be reckoned Leaf Curl in Scotland a disease with features distinguishing it sharply from the former and which has recently caused widespread destruction of the Norfolk Giant variety in Scotland. Lloyd George is a " carrier " of this disease, which however has not been observed south of the Border.

To sum up a complicated position. By the use of Baumforth's B, Norfolk Giant, St. Walfried and the best available Lloyd George as " Differential indicators ", the Mosaic 1 and Mosaic 2 categories have been related to a number of symptom sub-categories or types. Thus Cadman (unpublished work) has recently listed some eight symptom types on the highly sensitive Norfolk Giant, including Scottish Leaf Curl which itself comprehends a characteristic blotch symptom. Some of these categories are clearly themselves complex in origin and most probably share viruses in common with other types. In contrast to the eight Norfolk Giant symptom types, only three types of visual virus symptom have been so far distinguished on Lloyd George, an adequate measure of the widely contrasted virus reaction of the Norfolk Giant and Lloyd George varieties. Beyond the limits of the visual expression lies the limbo of " Symptomless degeneration " with its viruses as yet unidentified. For the ultimate interpretation of these raspberry symptom types in terms of their constituent viruses and virus complexes, a virus-free strain of Lloyd George and positive information on the natural vectors are essential prerequisites. Of these the former has recently become available from New Zealand, and as already noted, in 1946, Cadman and Hill transmitted each of the symptom types " carried " by the Amos Lloyd George selectively (i.e. each type by one species of insect) by the two common raspberry aphids *Amphorophora rubi* Kalt and *Aphis idaei* V. der G.

**Summary.**

Some account is given of the degeneration of strawberry and raspberry varieties in Great Britain during the past twenty-five years, and of research into the viruses and virus associations responsible for this, and their modes of spread and transmission.

## References.

Bawden, F. C. (1946). " Virus diseases of plants." *J. roy. Soc. Arts*, **94**, 136-68.

——— and Kleczkowski, A. (1945). " Protein precipitation and virus inactivation by extracts of strawberry plants." *J. Pomol.*, **21**, 2-7.

Harris, R. V. (1933*a*). " The strawberry Yellow-edge disease." *J. Pomol.*, **11**, 56-76.

——— (1933*b*). " Mosaic disease of the raspberry in Great Britain. 1. Symptoms and varietal susceptibility. *J. Pomol.*, **11**, 237-55.

——— (1940). " Mosaic disease of the raspberry in Great Britain. II. Experiments in transmission and symptom analysis." *J. Pomol.*, **17**, 318-43.

———, Bryce, A. D., and Foister, C. E. (1943). " Raspberry Leaf Curl." *Fruitgrower*, **96**, 51.

——— and King, M. E. (1942). " Studies in strawberry virus diseases. V. The use of *Fragaria vesca* L. as an indicator of Yellow-edge and Crinkle. *J. Pomol.*, **19**, 227-42.

King, M. E., and Harris, R. V. (1942). " Studies in strawberry virus diseases. IV. Symptom expression of Yellow-edge in the variety Royal Sovereign." *J. Pomol.*, **19**, 212-26.

Massee, A. M. (1935). " On the transmission of the strawberry virus Yellow-edge disease by the strawberry aphis." *J. Pomol.*, **13**, 39-53.

——— (1942). " Aphis transmission of strawberry Crinkle in Great Britain." *J. Pomol.*, **20**, 42-8.

Ogilvie, L., Swarbrick, T., and Thompson, C. R. (1934). " A note on a strawberry disease resembling the American ' Crinkle '." *Rep. Long Ashton Res. Sta. for 1933*, 96-7.

Prentice, I. W. (1946). " Resolution and synthesis of virus complexes causing strawberry Yellow-edge." *Nature*, Lond., **158**, 24.

———, and Harris, R. V. (1946). " Resolution of strawberry virus complexes by means of the aphis vector *Capitophorus fragariae* Theob." *Ann. appl. Biol.*, **33**, 50-3.

———, King, M. E., and Harris, R. V. (1946). " Experiments on virus degeneration of Huxley strawberry." *J. Pomol.*, **22**, 111-6.

# APPLE ROOTSTOCKS AS AN OUTDOOR HOST FOR MASS INFECTION AND FUNGICIDE TESTING

By M. H. MOORE

With recognition of the vast scope offered by synthetic organic chemicals as potential fungicides, an urgent need has arisen for preliminary testing methods on an intensive scale. Full-scale field trial, particularly with fruit trees, is a laborious and costly way of first testing numerous and "unknown" materials. Several laboratory and greenhouse precision testing methods have been devised in the last decade or so. Their primary function is to assess the fungicidal properties of the test materials, and in so doing to build up knowledge of the relationship between such properties and molecular structure with a view to further synthesis.

Bio-assay *in vitro* can reveal nothing about phytotoxic properties, except possibly by the dubious process of analogy with closely similar materials of known phytotoxic performance. Greenhouse tests *in vivo* introduce host-parasite and host-fungicide relationships, thus enabling further appraisal of fungicidal properties and preliminary assessment of gross phytotoxic properties to be made. But because the *in vivo* tests seek to rival the *in vitro* ones in the precision of standardized procedure, small, easily propagated and manipulated, quick-growing herbaceous plants are chosen as the host, and the use of controlled temperature and humidity chambers is desirable. The test pathogen obviously depends on the choice of host, and as organic materials are known to show pronounced specificity, it is unlikely that the results obtained against a pathogen of, say, potato or tomato can be directly translated with confidence into terms of fruit-tree pathogens of widely different genera and species. Precision tests are fundamentally necessary to provide facts on which further specific tests can be based, but such assay is not by itself necessarily the solution of disease-control problems.

One of the points made by some authors of precision *in vivo* methods is that the prescribed conditions necessarily limit both the number of plants that can be treated in any one experiment and the number of experiments that can be made. A similar limitation is true of established fruit trees in plantation trials because of the area of land and number of trees required. Extension of the facilities offered by either method would prove very costly, and a need exists for an intermediate stage in which large numbers of plants can be treated in mass, with perhaps less precision than obtains in laboratory and greenhouse testing, yet permitting of more detailed observation than is usually possible on a plantation scale. If the host were apple and the pathogen *Venturia inaequalis*, the direct application of results to the fruit plantation would be brought at least a stage nearer. The need for controlling Apple Scab has already proved a ready stimulus for much of the precision testing work undertaken, and, while this disease is of wide interest because of its importance in apple culture, the development of an outdoor method of mass infection and treatment might be applicable in some degree to other important fruit diseases.

Field trials of fungicides have sometimes failed to yield satisfactory results because of insufficient Scab-infection in dry weather, and the literature makes it abundantly clear that adequate moisture is the most important single factor necessary for infection, given a susceptible host and suitable inoculum. As it is easier to maintain humidity near the ground than several feet up, vegetatively raised apple rootstocks, which root easily and can be rapidly multiplied, were considered suitable as host material for preliminary studies. Several rootstock varieties are known to be very susceptible to Scab, and when correctly managed they readily produce a succession of annual shoots ideal for detailed observation work. Adequate experimental design should safeguard the accuracy ensured by precision methods in smaller compass, and it is obvious that, in conception, the *outdoor* use of rootstocks must be a concentration of field technique and not an extension of laboratory technique, though indeed, rootstocks in pots might prove suitable for this precision work. Natural infection should be the aim, and this must be aided by every convenient means, with a minimum of artificiality necessary perhaps to maintain the required humidity.

The early experiments have shown that complete covering of the rootstocks for all or part of the period of exposure to inoculum helps to maintain humidity, but clearly it yields a very unnatural environment for the host and is not desirable in other respects, especially as regards the known volatility of certain test chemicals. Moreover, glass covers, while allowing the passage of light, need much manipulation in quantity. Fabric can be more easily handled and stored, but it excludes light and might hinder the maintenance of humidity in certain circumstances. Side shelter by glass or fabric, particularly when the fabric is set up immediately around the plants, is open to similar objections varying only in degree. Experiments are in progress with natural and other shelter to keep off drying

wind, which rapidly lowers humidity. Artificial rain in some form, especially from a fixed sprinkler system that can be operated at will, was an asset in promoting humidity.

The merits of conidia and of ascospores as a source of infection were compared. For tests in spring conidia may have to be grown in artificial culture, because they may not then be available from natural sources. They must be applied in suspension, perhaps more than once in any one test to guard against unfavourable conditions for infection on any one occasion. Such manipulation would greatly add to the tedium of testing on a large scale. Naturally-ejected ascospores from dead leaves spread along the rows of rootstocks proved much more convenient, and the exposure to inoculum was prolonged over a period during which the aided environmental conditions were sometimes favourable for ready infection ; moreover, this method simulated what occurs in nature. A supply of scabbed leaves was collected from the trees in autumn just before leaf-fall, and kept till spring under natural conditions ; in this way leaves of only one apple variety are assured. The test fungicides were severally applied to randomized lengths of row prior to distributing the leaves containing ripe ascospores.

A similar method of mass infection has been successfully devised for Apple Canker (*Nectria galligena*), and intensive investigations are in progress on control measures. Evidence has been obtained that this use of rootstocks may be applicable also to preliminary assessment of the influence of nutrition on the incidence of disease, probably because the compact root system quickly responds to soil dressings.

The successful fruit-tree fungicide of the future may thus graduate from the chemist's test-tube through a precision test for fungicidal activity, thence to the host in modified form (e.g. apple rootstocks) with an outdoor mass-infection technique ; then possibly on to the established, cropping host on a further intensive scale (e.g. dwarf-pyramid trees), where phytotoxicity would be a first *critical* concern, and finally to the established plantation tree, an ultimate goal to be attained only perhaps by the few.

**Summary.**

A brief outline is given of the use of unworked apple rootstocks for outdoor mass infection by certain fungal pathogens of apple trees, and the application of the method to the evaluation of control measures, especially the testing of fungicides.

# PRELIMINARY REPORT ON *MONILIA FRUCTIGENA* AND *BOTRYTIS CINEREA* AS WOUND PARASITES OF COBNUTS AND FILBERTS*

By M. H. MOORE

A troublesome disease causing considerable loss of crop in nut plantations was reported in 1943 by several growers and described by Wormald (1944). Immature nuts began to rot in July and soon dropped, often in clusters where only one of the nuts was visibly affected. Wormald isolated several fungi, and most commonly *Monilia fructigena*, from rotting nuts, but stated that " until comparative inoculations . . . have been made the primary cause of Nut Drop and the factors conducive to severe loss remain undecided ".

Meantime, spraying experiments were conducted in a grower's plantation. Sulphur and copper fungicides, with and without lead arsenate, were compared, but though the trials were carried on over several seasons, little success was obtained and the disease continued to cause heavy losses every year.

Intensive spraying and inoculation experiments were undertaken on cobnuts in another grower's plantation in July, 1946. Effects of fungicide spraying (with colloidal-copper suspension), of inoculating by spraying with a conidial suspension of *Monilia fructigena* (from infected Czar plum fruits in the same plantation), and of piercing each nut while still soft-shelled with a steel needle were investigated separately and in combination, with appropriate controls. The fungicide was applied to individual clusters and allowed to dry immediately before spraying with the conidial suspension, followed by wounding.

All treatments except wounding were abortive : the fungicide failed to prevent infection ; the spore-suspension failed to increase it. Eighty-nine out of ninety-six artificially wounded nuts became infected within a week, and the clusters began to drop. Twenty-one out of one hundred and six nuts not artificially wounded rotted also, but in every case an obviously recent insect puncture was present. Where spore-suspension was not added, enough spores were evidently already on the nuts, or had alighted after wounding, to cause infection through the needle wound, for the nuts were not sterilized or protected, and infected apple and plum fruits growing above the nut bushes—a usual form of interplant in Kent—provided a ready source of inoculum.

Twenty-six infected nuts (100 per cent.) from the series that had been sprayed with fungicide and wounded but not inoculated were carefully collected, and a corresponding number of sound James Grieve apples—a variety highly susceptible to Brown Rot (*Monilia fructigena*)—were selected from plantation trees for inoculation experiments. Under sterile conditions in the laboratory a transfer was made from the " pith " of each rotting nut into a wound made in a corresponding apple. Six similar apples from the same source were alike wounded but not inoculated. All inoculated apples except two rapidly developed typical Brown Rot symptoms and bore the familiar buff-coloured spore-cushions of *Monilia fructigena* ; the controls remained sterile. Of the exceptions, one apple developed Grey Mould (*Botrytis cinerea*) and the other remained sterile ; its source of inoculum was visibly different from the rest, the nut being blackened in patches, not brown and completely rotting like the others. Transference to healthy cob-nuts under similar sterile conditions of small portions of the flesh of one of the twenty-four rotting apples and of the one rotted by *Botrytis* respectively caused rotting of the nuts, with production of typical fructifications. The controls remained sterile.

These two fungi, but *Monilia fructigena* most commonly in this instance, were thus shown to be wound parasites of cultivated hazel nuts, and it remained to find the natural wound agent in the plantation.

Careful search at this time showed that almost all primarily infected cobnuts and filberts bore long, tangential, oviposition tunnels and freshly-deposited unhatched eggs of Nut Weevil (*Balaninus nucum*),† of which there was a large population on the bushes on two farms examined. Some of the nuts and their husks were entirely brown ; others were just beginning to rot around the site of the puncture (Fig. 1) ; in yet others the rot was not visible until a weevil-punctured nut was cut across. Sometimes infection progressed from a punctured nut to an unpunctured one in the same cluster through the cluster base. In such instances the second nut was found to be rotting from the bottom upwards, often undetected until the husk was removed. Spore-cushions of the Brown Rot fungus

* Filberts are often used as pollinators in cobnut plantations.

† Identified by Dr. A. M. Massee.

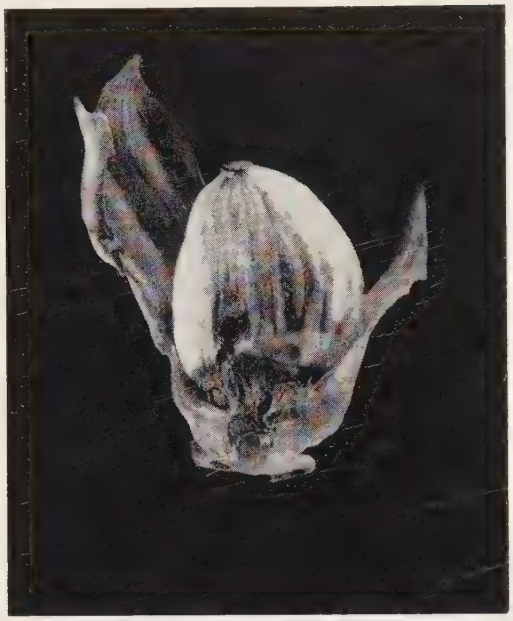

Fig. 1.
Cobnut rotting around oviposition puncture of Nut Weevil.

Fig. 2.
Brown Rot fungus producing spore-cushions on infected cobnuts.

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were found on many of the infected nuts in the plantation (Fig. 2). Not all oviposited nuts were infected.

Experiments on apples in the same season showed that a close parallel exists as regards Brown Rot infection of nuts and apples respectively, for there was a clear relationship between the incidence of this disease and prior attack by larvae of the Codling Moth (*Cydia pomonella*) as well as by Scab (*Venturia inaequalis*).

As with apples, so with nuts, the solution of the Brown Rot problem evidently lies largely in the control of certain insect pests and other wound-producing agents (Wormald and Moore, 1945). The nut spraying experiments showed that lead arsenate applied before late June did not materially reduce Nut Weevil attack ; the fungicides were ineffective against the rot fungi ; hence the results of spraying were not encouraging. Collaborative work with the Entomology Section is now in progress (see p. 38) to find a satisfactory spray or dust programme for Nut Weevil Control.

The writer is indebted to Mr. C. W. Neal and Mr. W. E. Gunyon for providing facilities for experiments on their farms, and for helpful co-operation.

**Summary.**

Evidence is given of the parasitism of cultivated hazel nuts by *Monilia fructigena* and to a less extent by *Botrytis cinerea* through oviposition punctures of the Nut Weevil (*Balaninus nucum*).

References.

Wormald, H. (1944). " Nut Drop—a disease of cultivated hazel nuts." *Rep. E. Malling Res. Sta. for 1943*, 56-8.

———, and Moore, M. H. (1945). " The control of Brown Rot of apples in commercial orchards." *Rep. E. Malling Res. Sta. for 1944*, 124-6.

## ENTOMOLOGY

# A NEW METHOD OF REARING THE FRUIT TREE RED SPIDER (*OLIGONYCHUS ULMI* KOCH) ON APPLE SEEDLINGS

By A. M. MASSEE

**Introduction.**

When using the Fruit Tree Red Spider (*Oligonychus ulmi* Koch) either for the biological testing of acaricides or for life-cycle studies, it is unavoidable that the mite and the egg cannot be seen adequately without the aid of a lens or binocular microscope, but certain modifications can be employed to enable the workers to handle this animal much more readily, especially for the biological testing of acaricides.

In past years, when the eggs of this mite have been used for testing acaricides, it has been the practice to collect branches of apple, plum or other fruit trees upon which eggs are laid. Shoots bearing eggs are cut and kept in the insectary or laboratory, where they are contained in jars of damp sand or water (Steer, 1938). Then provided the eggs are kept moist from time to time by spraying with tap water, some of the eggs—but not necessarily a large percentage—may hatch satisfactorily in late February and in March. The method has two very obvious drawbacks. First, it is not possible to estimate the percentage of eggs which will hatch, and experience shows that on cut shoots the number may be very low. Second, when examining the eggs under the binocular microscope after the tests have been made and hatching is considered complete, it is not possible to distinguish between eggs hatched after the treatment, if any, from those which emerged previously ; or even those sucked dry the previous autumn by predaceous insects such as *Blepharidopterus angulatus* Fall., *Anthocoris* spp. or by certain species of acari.

For the above reasons and also to facilitate the study of the life-cycle under laboratory conditions certain modifications of methods have been evolved.

**Apple Seedlings.**

In order to facilitate the study of the life-cycle and improve the standard of the biological tests of acaricides, apple seedlings have been raised to provide living plant material, which incidentally is readily available and easy to manipulate.

Apple seedlings raised from pips of the variety Worcester Pearmain, sown in sterilized soil, and contained in seed boxes, are used. The pips, which are obtained from cull fruit discarded from the packhouse, are sown in October, and the seed boxes are kept in a cold frame until February, when they are transferred to a cool greenhouse. Heating is avoided to prevent too rapid growth. Germination usually starts in February and as soon as the seedlings are sufficiently large to handle they are transferred to size " sixty " pots and are removed to the greenhouse or insectary. The main difficulty of growing apple seedlings under laboratory conditions is the fact that they are very subject to mildew, a condition which makes them quite unsuitable for breeding work.

By the above method many seedlings can be raised for testing purposes, and those subject to apple mildew in their early stages (about 20 per cent.) can be discarded. The variety Worcester was selected because it appeared to be less subject to mildew in the seedling state than other varieties used. Also Worcester seedlings have less hairy stems and the leaves are smoother, a condition favoured by the mites under natural conditions.

Should mildew develop on the seedlings during the summer months, it is advisable to spray them with a copper fungicide, since this spray is not toxic to the eggs or mites. Sulphur preparations must be avoided because they are toxic to the mites.

**Rearing Mites and Eggs for Biological Testing of Acaricides.**

(1) *Mites and eggs for summer tests.* When mites and eggs are required for conducting biological tests of acaricides during the summer months, the following method is suggested. Newly emerged adult female mites are selected from material collected in the field. Five such mites are transferred to the leaves of a seedling by means of a camel hair brush. The mites are allowed to move about freely ; a ring of petroleum jelly being placed around the base of each stem to prevent their escape.

Fig. 1.
Apple Seedlings " Worcester " used in the life-cycle studies of the Fruit Tree Red Spider.

Fig. 2.
Batch of Apple Seedlings " Worcester " used in the biological tests of Acaricides of the Fruit Tree Red Spider.

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In addition one adult male is transferred to each seedling to ensure fertilization, since the female is parthenogenetic, and the unfertilized females produce only males.

In practice it is not difficult to recognize the newly matured female, since it remains near to or attached to the recently cast skin of the last moult for some hours after hatching.

Each female lays about thirty eggs, thus the number deposited by five females would be one hundred and fifty, which proves to be a suitable number to examine on a seedling apple.

When immature mites are required the dipping or spraying treatment is delayed until the eggs have hatched. The advantage of this method is that the seedlings can be kept under natural conditions throughout the experiments.

(2) *Eggs for winter tests.* When material is required for winter egg tests a batch of the smaller seedlings should be selected, and mites transferred to them for breeding purposes about the middle of July. Five female mites and one male are transferred to each seedling as described above, and by the end of the growing season (October) about one hundred and fifty winter eggs will be deposited on the main stem of each seedling. Each seedling must be examined periodically to ensure none of the mites has fallen off the seedlings or perished. The few noted missing should be replaced by others. It is a mistake to transfer too many mites to a seedling since the egg population will become too large to count quickly and accurately.

When the winter eggs have all been laid the seedlings are plunged in open ground where they remain until required for testing purposes. Immediately the dipping or spraying tests have been made the seedlings are returned to the plunging ground and remain there until hatching has finished. The seedlings are then returned to the laboratory, the stems cut-off at ground level as required and examined under the binocular ; an accurate record can then be obtained of the percentage of hatched eggs.

(3) *Life-cycle investigations.* The life-cycle of the mite cannot be studied in the field because of its minute size, and of the difficulty of keeping specific mites under observation by enclosing them in muslin bags or glass cells ; much of this detailed work must therefore of necessity be carried out in the laboratory. For this purpose seedlings similar to those used for the biological testing of acaricides have proved ideal (see Figs. 1 and 2). Batches of seedlings are brought into the laboratory from time to time, and the mites are reared upon them. By this means detailed data have been obtained of the number of eggs deposited by single females, the number of moults made by individuals and other details not previously noted. In fact the complete life-cycle can be followed on the living plant, which must be preferable to rearing individuals on leaves in glass cells or on shoots partly submerged in water.

**Acknowledgement.**

The writer is greatly indebted to Mr. A. Tidy, in charge of experimental greenhouses, for his assistance in raising the apple seedlings and evolving a technique suitable for this type of investigation.

**Summary.**

An account is given of the raising of apple seedlings suitable for rearing the Fruit Tree Red Spider (*Oligonychus ulmi* Koch) upon, and for making biological tests of acaricides upon the eggs, immature forms and adult stages of this mite on living plant material.

## Reference.

Steer, W. (1938). "Laboratory Methods for the Biological Testing of Insecticides." *J. Pomol.*, **25**, 338-55.

# NOTES ON SOME INTERESTING INSECTS OBSERVED IN 1946

By A. M. MASSEE

**1. The Hop Root Weevil** (*Epipolaeus caliginosus* F.).

This weevil has been referred to once previously in these notes when it was reported damaging the roots of hop at Tenbury, Worcestershire. Since then it has been reported on several occasions, and appears to be well established in the Hunton district of Kent. Further records have been received from Worcestershire from time to time.

The grub of this weevil causes injury by tunnelling into roots of the hops, and at Hunton the roots and stems of one-year-old sets were badly affected. The injury was first detected in March and at the end of April some of the hills were removed because of the injury caused by this weevil. The injured roots soon decay, causing the grubs to leave and find fresh food, and one root after another is attacked indiscriminately. The grub is very similar to that of the Clay Coloured Weevil. It is a dirty creamy white, with a brown head. The fully grown grub is about $\frac{3}{8}$ in. long. When at rest the grub attains a characteristic attitude with the apex of the abdomen curved, and almost touching the head.

This weevil is not very abundant in Kent, but appears to be widely distributed. Its occurrence in the Kentish hop gardens will be watched with interest.

**2. The Nut Weevil** (*Balaninus nucum* L.).

The Nut Weevil has been prevalent during the past few years, and appeared to have reached its peak in 1945, when very severe attacks were noted in the Otham district. On one farm the nuts were gathered later than usual owing to labour shortages, and a large proportion of the nuts were infested with weevil grubs. Attacks were also serious in other parts of Kent. Under normal conditions the nuts are gathered at the end of August, and at that period the presence of the grub is not so readily detected, and the grower is able to dispose of his crop. If, however, marketing of the crop is delayed until October the weevil injury is much more conspicuous and the market value greatly diminishes.

Freshly emerged adult weevils were noted in nut plats at Otham and West Peckham respectively at the end of April.

**3. The Hop Flea Beetle** (*Psylliodes attenuata* L.).

It is very curious that the Hop Flea Beetle persists in the hop gardens in the East Malling district every year, and that gardens a few miles away are never unduly worried by this flea beetle, although it is always present in small numbers. It proved to be abnormally common in the hop gardens at the Research Station in May and early June, when the feeding of the adults on the tender bines and leaves prevented the hills growing away normally. A second attack occurs in some seasons during the latter part of August and September, and one occurred at East Malling in 1946. The adults of the summer generation mature in August, and feed on the hop leaves, and during wet weather they shelter in the cones of the hops. Thus in the very wet August of 1946 considerable damage was caused to the cones by these beetles, since many were present in the cones most of the month.

Undoubtedly the flea beetle causes most injury to newly planted hops and young seedlings, and several instances of damage were noted in various parts of Kent.

It seems likely that the new flea beetle dust (benzene hexachloride) will provide a satisfactory remedy against this insect.

**4. Clay Coloured Weevil** (*Otiorrhynchus singularis* L.).

Adults of the Clay Coloured Weevil caused considerable injury to the new growths of a recently planted hop garden at Ditton, and to young hop sets at the Research Station during May. The damage is caused by the weevils girdling the stems, nibbling out the tips of the shoots and defoliating the bines.

This insect is very difficult to eradicate in the field for two reasons. It feeds only after nightfall and may travel a considerable distance during the night, thus often making it necessary to treat the whole garden. Also the hop bines grow so quickly during the spring months that an insecticide applied during the day-time will not protect the new growth made during the warm evenings, and it is upon these very young tips that the weevils prefer to feed. Experience shows that spraying with an arsenical spray during a cold spell—when little or no new growth will be made—combined with

constant moving of the ground checks this pest and allows the bines to grow away. It is indeed curious that the weevil is never troublesome once the bines have attained a length of three feet or so.

This weevil also caused serious damage to a plantation of Lloyd George raspberries at Dalgetty, near Brechin, Angus, Scotland, in May and June. Similar damage had been reported the previous season. About three acres in the centre of a large plantation were affected, and the crop was much reduced. The injury was caused by the weevils feeding upon and skeletonizing the leaves, by their nibbling through the stems of the fruit trusses and materially reducing the size and vigour of the current year's growths. This type of damage has been noted in the South-East of England, but the amount of injury was not comparable to that noted in Scotland. Should outbreaks of this nature occur regularly in the Scottish raspberry growing districts, it will be imperative to study this weevil in all its aspects and devise adequate control measures against it.

**5. Apple Fruit Rhynchites** (*Rhynchites aequatus* L.).

The Apple Fruit Rhynchites is recognized as a troublesome pest of apple and to a lesser extent of plum, pear and damson. During the last week of May many were noted on some seedling cherry trees at the Research Station. Many of the fruits were considerably mal-formed by their feeding on the flesh, the punctures penetrating up to the depth of $\frac{1}{4}$ in., and it was common to find up to seven or eight punctures on one fruit. The eggs of the weevil were not found in the cherry fruits, although they were prevalent in apple fruitlets at the same period.

A bad outbreak might have a serious effect upon the market value of the cherries, and should further attacks occur another season, they must be checked before the crop is ruined.

**6. *Barypithes pellucidus* Bh.**

This small black weevil, with short blunt snout, and covered in long grey hairs, is prevalent in the raspberry fields of Lingfield and Addington in Surrey. It feeds on the foliage and is most commonly found during May. When disturbed it readily falls to the ground and is thus frequently overlooked. A closely allied species *Barypithes araneiformis* Sk. attacks both raspberry and strawberry in Kent, but *B. pellucidus* has not been found on fruit outside Surrey. In Kent *B. pellucidus* Bh. occurs at the outskirts of woods, etc., amongst dead, dry leaves, in moss, etc. Neither of these insects is regarded as economic, but their presence must be borne in mind, since it will be remembered that, as recently as 1928, the Apple Fruit Rhynchites was looked upon as unimportant and now it is regarded as an important pest on top fruits.

**7. Cockchafer** (*Melolontha melolontha* L.).

This well-known chafer beetle can best be described as a mischievous beetle which not infrequently gnaws the flesh of apple and pear fruitlets and renders them unsaleable. This chafer beetle proved to be unusually common at Walmer, Kent, in the latter part of May, and severe damage was caused by the adults feeding upon the fruits of peaches and nectarines growing on wall trees. Some fruitlets were so badly eaten that most of the flesh had been removed. Fortunately this attack was confined to a few trees in a garden. A different story might have been told had the outbreak occurred in one of the larger fruit growing districts of Kent.

**8. Pea and Bean Weevil** (*Sitones lineatus* L.).

The Pea and Bean Weevil is well-known to the agriculturist since it is a serious pest of peas, beans, clover and many other leguminous crops.

This weevil also occurs in small numbers on fruit trees, particularly apple, but normally it is not economic. It may, however, cause considerable damage to newly planted apple trees by feeding on the foliage, since it has a voracious appetite. Such an attack was noted on the Research Station at the end of July in a field of maiden apple trees. Field peas were growing under the young trees, and when the peas had been gathered and the haulm removed, the weevils migrated to the trees above and fed on the tender leaves. The feeding continued for about three weeks, and then the weevils dispersed.

**9. Scarcity of Ladybird Beetles in Kent.**

The two spot Ladybird Beetle (*Adalia 2-punctata* L.) and the seven spot Ladybird Beetle (*Coccinella 7-punctata* L.) are very common beneficial insects in the fruit and hop growing districts of Kent during the spring, summer and autumn months. Last spring, however, ladybird beetles were noted to be less common than usual, and their populations did not increase notably during the summer months. The "niggers" (grubs), a familiar sight in the hop gardens during the summer and again at hop picking time, were very scarce. It is usual to find ladybird beetles and their grubs feeding amongst colonies of greenfly which infest apple and other fruits.

It is very difficult to account for the low populations of ladybird beetles during 1946, particularly as their chief source of diet was as plentiful as usual, but the cold, wet season might well be the cause. It has been noted in previous years that the ladybird populations increase much more rapidly in prolonged dry summers.

**10. Beneficial Ground Beetles Killed by DDT.**

During the last week of March, 1946, eight and a half acres of apples, consisting of Lane's, Derby, Grenadier and Laxton's, growing in a cultivated orchard at Higham was sprayed with a DDT emulsion (2 lb. per 100 gal.) at the rate of 1,000 gallons per acre. A power sprayer was used with a pressure of 500 lb. per square inch. The spray was applied to control Apple Blossom weevil, a pest of many years' standing in that particular plantation. Additional spray was applied to the headlands and the outside portion of a belt of woodland on three sides of the plantation.

The plantation was visited again on 3rd April and tens of thousands of dead ground beetles were found under the trees. These beetles had collected in any hollow or depression in the ground, in cart ruts, etc. Amongst this vast mass of dead coleoptera four species of beneficial ground beetles were the most numerous. They are as follows : *Harpalus aeneus* F., *Amara plebeia* Gy., *A. lucida* Df., and *A. communis* Pz. The Chrysomelid beetle, *Gastroidea polygoni* L. was also very common. It should be noted that ladybird beetles, earwigs, lacewing flies and spiders often prevalent in apple plantations at this period of the year were not found. The residual effect of the DDT lasted until the latter part of April, after which the insect population of the plantation gradually built up again, and at blossom time ladybird beetles, several species of Clavicorn beetles (beneficial pollinating species) and green and brown leaf-eating weevils were prevalent and comparable in number with those in a plantation adjoining, which received no DDT.

Finally, the Apple Blossom Weevil did not survive this very drastic treatment, since no " capped blossoms " were observed in the plantation treated with DDT.

**11. Pith Moth** (*Blastodacna atra* Haw.).

Although the Pith Moth is a persistent pest in the old apple orchards of Kent, it is not often noted by the fruitgrower. This insect is very plentiful in the Canterbury district, often causing considerable damage to the buds of young trees. The small, pinkish-brown caterpillar bores into the stems of the flower trusses and shoots and frequently hollows out the terminal bud. This type of injury is most noticeable at blossom time, since affected blossoms wilt and die. In one attack near Canterbury, however, the damage was apparent by the end of March, and was very considerable. A similar infestation was noted at East Malling in 1928, when most of the terminal buds were affected and killed, and subsequently weak lateral growths were produced.

This pest is very difficult to eradicate owing to the obscure feeding habits of the larva, and a complete knowledge of its life-cycle is very desirable to achieve this end.

**12. Tortrix Moth Infesting Orchards.**

During the last four or five years there has been a steady increase in the population of Tortricid larvae infesting apple and plum and to a lesser extent pear and cherry orchards. This build up of populations was very apparent in the East Malling district in 1946. Several species of Tortricids were noted and the damage caused by their larvae feeding first on the foliage and later on the fruitlets was considerable.

The commonest species proved to be *Cacoecia podana* Scop. which is equally common on apple, plum and cherry. Another widely distributed species is *Ditula angustiorana* Haw. which infests apple, plum, damson and occasionally apricot. A third species, namely, *Spilonota ocellata* Fabr. is also abundant and it feeds on top and soft fruits indiscriminately, and of the latter, currant and cultivated blackberry are the chief hosts. Among other species, *Cacoecia crataegana* Hüb. is not uncommon, but it causes less injury to the developing fruitlets than for instance *C. podana* Scop.

The Tortrix larvae are very susceptible to DDT dusts and sprays, and where this new insecticide has been applied to orchards from bud burst to the green-cluster stage, there has been a marked reduction in the Tortrix population. Further research is necessary, however, to determine the correct strength of insecticide to use, and the best time to apply it.

**13. Ghost Swift Moth** (*Hepialus humuli* L.).

The caterpillar stage of the Ghost Swift Moth or Otter is a well-known root feeding pest of strawberry, raspberry and hop, and in some seasons it may cause considerable harm, particularly to cultivated strawberries.

A very serious outbreak occurred in a commercial strawberry field near Faversham, Kent. The variety Royal Sovereign was most badly affected and plants in their third year of cropping suffered

most severely, the crop being greatly reduced. One- and two-year-old plants were attacked to a lesser degree.

This and other attacks noted in the same district proved interesting and unusual, since the pest persists season after season in cultivated soil. It is usual to find infestations on newly cultivated land where such wild host plants as burdock, deadnettle and dandelion have been growing freely, because these plants are the natural hosts of the insect. Also strawberries are frequently attacked by this insect when they are planted on recently grubbed hop land. The caterpillars of the Ghost Swift being very partial to the roots of hops, high populations occur in many gardens.

This insect is very difficult to eradicate in the field, and it is hoped one of the new soil insecticides may prove efficacious against it. The recognized treatment of a soil dressing of naphthaline is not very efficient.

**14. Raspberry Moth** (*Lampronia rubiella* Bjerk.).

The Raspberry Moth is correctly regarded as a major fruit pest in Scotland, but fortunately it is less common in England, and is only common locally in the south-east counties. A few specimens may be found, however, in most raspberry plantations, and every now and again troublesome outbreaks occur. Such an infestation occurred in a three-acre field of Norfolk Giant at East Malling. Indeed the infestation was so severe that practically all the young growths were withered or dead, the insides of the shoots being tunnelled and eaten away by the red caterpillars. A small infestation was noted the year previously, but the damage was not serious. The crop was completely ruined in 1946, and the grower wisely decided to cut down and burn immediately (in June) all the established canes leaving only the new growths. This drastic action proved very efficient, since most of the caterpillars were destroyed, thus preventing the moths laying their eggs on the new canes during the summer months. A complete account of the life-cycle of this insect is not yet available, and this subject presents a golden opportunity for a young student of Entomology to make a valuable contribution to his Science.

**15. Apple Leaf Miner** (*Lyonetia clerkella* L.).

The Apple Leaf Miner is a peculiar and interesting insect, occurring very irregularly in nursery and young apple plantations. For example it was very common in 1923 in the Maidstone district, since that time it has been scarce, until 1946, when it was prevalent in the apple stock beds at East Malling and also on the tender foliage of newly-planted trees.

The caterpillar stage of the Leaf Miner injures the leaves usually those growing at or near the tips of shoots, by making winding galleries within the leaf tissue. Several caterpillars may attack a single leaf, which causes the leaf to curl, turn brownish and brittle. Attacked trees become defoliated prematurely.

Minor attacks by this insect were noted in various parts of Kent, and two reports came from the Midlands. The most severe attack ever brought to the notice of the writer came from Bray, County Wicklow, near Dublin, Ireland. The varieties Lane's, Gladstone and Golden Spire were affected and the damage was very considerable.

**16. Moths of the Winter Moth Group.**

In last year's notes reference was made to an unusually heavy infestation of winter moths in a cherry orchard at East Malling, although the trees in question had not been defoliated by winter moth caterpillars in the spring months earlier in the year. The outbreak seemed unaccountable, but since then further observations made in adjoining orchards have fully explained this phenomenon.

In December, 1945, very few wingless females of the Winter Moth were observed in a cherry orchard at East Malling which was partially defoliated by the caterpillars of this moth earlier in the year. In December, 1946, however, these moths were very prevalent, although as already stated the previous spring the caterpillar attack was negligible. The explanation is as follows. When the caterpillars become fully fed during the first and second weeks of June, they fall to the ground, burrow below the surface and pupate in the soil. During November and December some of the moths emerge from the pupae and proceed to the trees for egg laying purposes. In some seasons, however, most of the pupae remain in the soil throughout the winter and do not emerge until the autumn of the following year. It seems reasonable to suggest that this is what took place in the orchard referred to in last year's notes.

**17. Plum Sawfly** (*Hoplocampa flava* L.).

In these notes for 1945 a brief account was given of the scarcity of Plum Sawfly in the East Malling district. This season the position was just the reverse, abnormal infestations being noted in the Maidstone and Malling districts, the susceptible variety Czar being heavily infested. It is not possible

to account for the fluctuations of populations of this insect from season to season in detail, but the following observation may partially explain it. A number of fully fed larvae were collected in May, 1944, and were kept in peat moss in glass containers in the laboratory. A few adults emerged in April, 1945, but the majority remained in the soil until April, 1946, when they emerged. Some of the apple sawfly larvae or pupae usually overwinter in the soil for two seasons before emerging, and under laboratory conditions at least the plum sawfly follows the same habit.

The emergence period of many of our fruit pests is probably delayed by the conditions prevailing at the time, and this fact must be recognized when working out the life-cycle of any given insect.

**18. Cherry Shield Bug** (*Pentatoma rufipes* L.).

The Cherry Shield Bug was very common in some cherry orchards at East Malling last May, as in 1935. The nymphs of several instars were present on the same trees, but it was not possible to determine what they were feeding upon. These bugs were very active in sunny periods, continually stalking up and down the branches, as if in search of their prey. The trees in the orchard had been greasebanded the previous autumn, and on the trees where the grease was still functioning properly the immature bugs were prevented from obtaining access to the limbs and branches.

This bug can emit a most unpleasant smell, and cherry pickers strongly resent its presence in an orchard at picking time ; they have been known to refuse to pick the fruits from trees where these bugs congregate. Actually the bug is quite harmless, and it is merely the appearance and smell of the insect that makes it disliked.

**19. Oat-Apple Aphid** (*Rhopalosiphum prunifioliae* Fitch).

Although the Oat-Apple Aphid is widely distributed in the fruit growing districts of this country, it is not an important fruit insect when orchards are properly cared for and receive the routine winter wash.

It frequently infests ornamental crab apples and quince stocks in the nursery bed. A very heavy infestation was noted on the large fruited Japanese Quince (*Chaenomeles* (*Cydonia*) *cathayensis*) growing in a garden at Leybourne at the end of May. The infestation was confined to this variety, although other suitable host plants were growing near at hand.

**20. Peach Aphid** (*Anuraphis amygdalis* Buck.).

This aphid is frequently a serious pest to apricots, peaches and nectarines growing under glass, but it rarely causes harm to these fruits when grown in the open. Several bad attacks were seen on wall peaches in the East Malling district at the end of May. This insect may prove very troublesome if not checked, because it curls up the leaves and checks the growth, which later results in undersized fruits, which do not ripen evenly.

This insect was also found infesting Marianna plum stocks at East Malling and also in Mr. N. H. Grubb's garden at Leybourne at the end of May. This record is not without interest since Marianna is not usually subject to aphid attack.

Normally the aphides continue to feed on the peaches, etc., throughout May and June, then become winged and migrate elsewhere, returning again in the autumn. At East Malling, however, the peaches were not reinfested again in the autumn, and the attack must be regarded as a chance infestation.

**21. Flat Scarlet Mite** (*Tenuipalpus galber* Donn.).

The Flat Scarlet Mite may be found on the undersurfaces of the leaves of pear and apple during the spring and summer months in unsprayed orchards throughout Kent. The mite also feeds on moss and lichen, and it hibernates in cracks and crevices of the bark during the winter months. This mite was very common in the Sittingbourne area in the spring, and the population was so high on some of the trees that growers thought they were having their first experience of a bad attack of the Fruit Tree Red Spider. There is no evidence, however, that it causes any damage to the tree, and it rarely occurs in the well-sprayed orchard because a tar oil winter wash completely eradicates this minute acarus.

**Summary.**

Notes are given on twenty-one insect pests and mites noted in 1946, and reference is made to the effect of DDT upon certain beneficial Carabid beetles. The scarcity of ladybird beetles is also referred to.

## PLANT PROTECTIVE CHEMISTRY

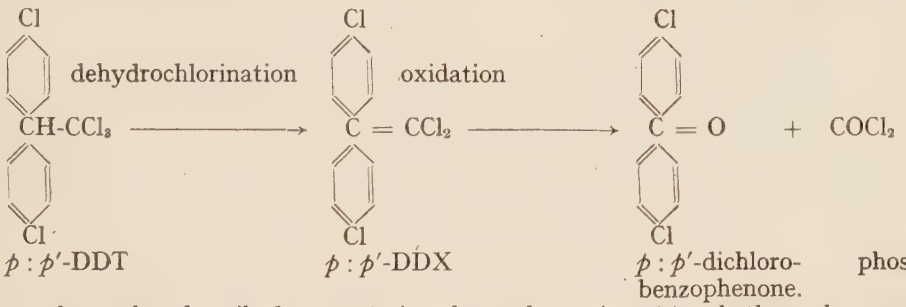
# THE FORMATION OF PHOSGENE FROM DDT AND RELATED COMPOUNDS

By J. K. EATON

**Introduction.**

A statement has been made in the press (Anon., 1945) that phosgene had accidentally been evolved, with fatal results to a number of small animals, when a horticultural dust containing DDT was mixed with copper oxychloride. This was a report in general terms unsupported by detailed evidence, and although the formation of phosgene from DDT and copper oxychloride seems unlikely, the matter called for investigation.

If phosgene were to be formed from DDT, it might be by oxidation, possibly following dehydrochlorination to 1 : 1-dichloro-2 : 2-bis(*p*-chlorophenyl)-ethylene (*p* : *p*′-DDX). Fleck and Haller (1944) have shown that such dehydrochlorination can be promoted by a number of inorganic compounds, e.g. ferric chloride. The formation of phosgene through the intermediate compound may then be represented :




The work to be described was designed to determine (1) whether phosgene is evolved when technical DDT, its major components or the ethylene compound (*p* : *p*′-DDX) are mixed or heated with certain pest and disease control materials that might, in certain circumstances act as oxidizing agents, and (2) the conditions of oxidation most likely to produce phosgene from *p* : *p*′-DDT and a number of related substances including some occurring as impurities in technical DDT.

**Experimental.**

*Materials examined.*

DDT (Geigy), a technical product containing 80 per cent. *p* : *p*′-isomer.

*p* : *p*′-DDT. 1 : 1 : 1-trichloro-2 : 2-bis(*p*-chlorophenyl)ethane. m.p. 108-109° C. Prepared from technical DDT by recrystallization from ethyl alcohol.

*o* : *p*′-DDT. 1 : 1 : 1-trichloro-2-*o*-chlorophenyl-2-*p*-chlorophenylethane. m.p. 74·0-74·5° C. The major component of technical DDT other than *p* : *p*′-DDT (Haller *et al.*, 1945).

*p* : *p*′-DDD. 1 : 1-dichloro-2 : 2-bis(*p*-chlorophenyl)ethane. m.p. 108·5-110° C. A component of technical DDT (Haller *et al.*, *loc. cit*). Prepared by the method reported by Hall (1945).

*p* : *p*′-DDX. 1 : 1-dichloro-2 : 2-bis(*p*-chlorophenyl)ethylene. m.p. 88-89° C. Prepared by the method of Haller *et al.*, *loc. cit.*

These substances were mixed with the following materials and evidence of reaction sought.

*Pest and disease control materials.*

Copper oxychloride (dry).
D.N.C. (3 : 5-dinitro-*o*-cresol). A 2 per cent. solution in petroleum oil (spindle type).

*Oxidizing mixtures.*

Glacial acetic acid and chromic anhydride.
Concentrated sulphuric acid and potassium dichromate.

The aniline method for the determination of phosgene was used (Olsen *et al.*, 1931). Powdered antimony metal was employed to remove chlorine and other interfering gases where present, since mercuric sulphide as used by these authors was not found effective.

After mixing, the substances under examination were heated at 100° C. for two hours under a reflux condenser. The gaseous products of reaction were drawn by a current of dry air through a guard tube to remove interfering gases and passed into a filtered saturated solution of aniline in water. Any carbanilide formed was filtered off through a tared G3 sintered crucible, washed with a filtered saturated solution of carbanilide in water, dried at 80° C. to constant weight, and its identity checked by its melting point and mixed melting point with authentic carbanilide.

## Results.

1. *Pest and disease control materials.*

No phosgene was found when technical DDT, *p* : *p*′-DDT, *o* : *p*′-DDT, *p* : *p*′-DDD or *p* : *p*′-DDX was mixed or heated with dry copper oxychloride or when technical DDT or *p* : *p*′-DDT was heated with D.N.C. in petroleum oil.

2. *Various oxidizing mixtures.*

On oxidation with chromic anhydride-glacial acetic acid mixture, technical DDT, *p* : *p*′-DDT and *p* : *p*′-DDX each evolved carbon dioxide but no phosgene was detected. One molecule of *p* : *p*′-DDX was found to yield one molecule of carbon dioxide and 1·8 molecules of hydrochloric acid, while *p* : *p*′-dichlorobenzophenone, m.p. 146·5° C., was isolated from the reaction mixture (Haller *et al.*, 1945). The identity of this substance was confirmed by its conversion into *p* : *p*′-dichlorobenzophenone oxime, m.p. 135·5° C.

When heated with potassium dichromate-sulphuric acid mixture, technical DDT, *p* : *p*′-DDT, *o* : *p*′-DDT and *p* : *p*′-DDD yielded phosgene, the yields being 30-40 per cent. theoretical for *p* : *p*′-DDT, 5-10 per cent. for *o* : *p*′-DDT, and 1-5 per cent. for *p* : *p*′-DDD, based on the formation of one molecule of phosgene from one molecule of the substance. In the case of the ethylene compound *p* : *p*′-DDX complete decomposition appeared to occur and no phosgene was found.

*p* : *p*′-DDX was also subjected to oxidation by acid permanganate, alkaline permanganate, hydrogen peroxide, and copper oxide, but in no case was phosgene detected.

## Conclusions.

The possibility that DDT or its technical components may evolve phosgene when mixed or heated with certain pest or disease control materials has been examined. As no phosgene was detected when DDT or any related substance was mixed and heated with copper oxychloride or with D.N.C. in petroleum oil, the investigation was extended to determine the conditions of oxidation necessary to produce phosgene from these compounds. It was found that a potassium dichromate-sulphuric acid mixture alone among the oxidizing agents used yielded phosgene from technical DDT and its major components.

No phosgene was obtained by any means tried from the ethylene compound (*p* : *p*′-DDX), suggesting that phosgene is unlikely to be formed from DDT by a mechanism involving the intermediate formation of this substance.

## Summary.

A reported evolution of phosgene on mixing DDT and copper oxychloride has not been confirmed. Only under conditions of vigorous oxidation not likely to be encountered in agricultural practice has phosgene been produced from DDT and certain related compounds.

## References.

Anon. (1945). "A DDT danger." *The Times*, London, 10th December.

Fleck, E. E., and Haller, H. L. (1944). "Catalytic removal of hydrogen chloride from some substituted α-trichloroethanes." *J. Amer. chem. Soc.*, **66**, 2095.

Hall, S. A. (1945). "Insecticides, insect repellents, rodenticides and fungicides." *C.I.O.S. Report. Item 24, File XXVI-73*, H.M. Stationery Office, London.

Haller, H. L., *et al.* (1945). "The chemical composition of technical DDT." *J. Amer. chem. Soc.*, **67**, 1591.

Olsen, J. C., Ferguson, G. E., Sabetta, V. J., and Scheflan, L. (1931). "Quantitative determination of phosgene." *Industr. Engng. Chem.* (*Anal.*), **3**, 189.

# HOPS

# PROPAGATION TRIALS WITH HOPS

## IV. FURTHER TRIALS IN PROPAGATION BY SOFTWOOD CUTTINGS

By F. H. BEARD and DOROTHY J. WILSON

**Introduction.**

During 1945 preliminary trials were carried out at East Malling to test the possibilities of raising hops commercially from softwood cuttings (Beard and Wilson, 1946), a method already shown to be possible under greenhouse conditions by Bailey (1939). A further series of trials, in 1946, was designed to throw further light on points that emerged from those of the previous year. The general technique (frames, compost, etc.) employed in these trials was the same as before, and need not therefore be described here. Weather conditions during the summer of 1946 were particularly unfavourable to the growth of hops and this may account for the much poorer takes obtained even in the more successful treatments. All trials were designed in randomized blocks ; each frame contained a complete replicate of all treatments involved in any one trial, and each experimental plot consisted of ten cuttings.

**Basal Shoot Cuttings.**

The method of obtaining this type of cutting was described in the account of the 1945 experiments. In these trials cuttings made from well-matured shoots (over 2 ft. long), taken from parent plants which had received a light earthing up as growth started in the spring gave the best results. All cuttings used in the 1946 trials were therefore made from this class of shoot. (See Fig. 1.)

**Varietal differences in response to growth substance treatment.**

It was found in the 1945 experiments that Fuggle cuttings were adversely affected by treatment with $\beta$-indolyl-butyric acid at 25 p.p.m. This effect had not been anticipated, therefore the various trials were not designed to show if the adverse effect noted with Fuggle was peculiar to that variety or whether other varieties would react similarly. For the 1946 experiments three varieties, Fuggle, Eastwell Golding and Bullion were selected. Eastwell Golding was chosen to represent the Golding group of English hops which is of very different habit to the Fuggle, while Bullion represented the new hybrid varieties (*H. Lupulus* × *H. americanus*) raised by Professor Salmon, since " strap-cuts " (hardwood cuttings) of this variety had shown a slight favourable response to treatment with $\alpha$-naphthalene-acetic acid (Beard, 1944). Although the hills of all three varieties were earthed up when growth started there was considerable difference in the amount of initial rooting found when the shoots were taken from the parent plants in May and June. Fuggle shoots were the best rooted and Bullion the most poorly rooted. The growth substance used was $\beta$-indolyl-butyric acid and it was applied at two concentrations of an aqueous solution (5 and 10 parts per million) and two concentrations of an alcoholic dip (2·5 and 5·0 milligrams per c.c. in 50 per cent. alcohol). Control treatments of water only and 50 per cent. alcohol only were also included. Cuttings which were to be treated with plain water or the aqueous solutions were prepared the day before planting and placed overnight 1½ in. deep in the water or the solutions. Cuttings for alcoholic treatment were obtained on the day of planting and the basal ½ in. of each cutting dipped in the appropriate liquid just before planting.

There were five replicates of each treatment. Two frames were planted on 21st May and three on 4th June, the time lag being due to lack of material occasioned by the cool weather and consequent slow growth of the parent plants. The rooted cuttings were lifted in November and graded into " good sets " suitable for planting out, " smalls ", that could be grown on in a nursery for a season, and plants which though alive were useless. Table I gives the mean percentages of " good sets " and " smalls " for each variety and treatment.

There were very large differences between the results in the five frames and had the take in all been as good as that in the first two (planted 21st May) the results would have been easier to interpret. However, statistical examination of the percentages of good sets did show some differences. Eastwell Golding gave superior results to Fuggle and Bullion. This may have been due to the better rooting of the cuttings when planted, a factor shown to be important in 1945. Dipping in alcohol was definitely

harmful; and where the growth substance was applied in this way, the results were very poor. There was no significant difference between growth substance treatments in water and their control. In neither medium was there any effect of strength of growth substance.

TABLE I.

EFFECT OF GROWTH SUBSTANCE ON BASAL SHOOT CUTTINGS OF THREE VARIETIES.

MEAN PERCENTAGES OF SETS LIFTED, NOVEMBER, 1946.

| | Eastwell. | | | Fuggle. | | | Bullion. | | | Mean. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Good. | Small. | Total. | Good. | Small. | Total. | Good. | Small. | Total. | |
| Alcohol control .. | 26 | 18 | 44 | 12 | 12 | 24 | 8 | 12 | 20 | 29 |
| 2·5 mg./c.c. dip .. | 10 | 10 | 20 | 0 | 0 | 0 | 6 | 0 | 6 | 9 |
| 5·0 mg./c.c. dip .. | 6 | 2 | 8 | 4 | 2 | 6 | 6 | 0 | 6 | 7 |
| Water control .. | 44 | 12 | 56 | 26 | 6 | 32 | 10 | 6 | 16 | 35 |
| 5 p.p.m. solution .. | 36 | 12 | 48 | 20 | 4 | 24 | 10 | 4 | 14 | 29 |
| 10 p.p.m. solution .. | 34 | 4 | 38 | 24 | 2 | 26 | 12 | 14 | 26 | 30 |
| Mean .. .. | 26 | 10 | 36 | 14 | 4 | 18 | 9 | 6 | 15 | 23 |

**Varietal differences in response to growth substance treatment among the Wilt-resistant varieties.***

The 1945 trials showed that four of these varieties (OM26, AEE55, OR55 and OJ47) could be raised from untreated basal shoot cuttings, but in view of the markedly adverse effect of growth substance treatment noted with Fuggle, it seemed important to see how the wilt-resistant varieties responded to treatment. In 1946, another variety, FF21, not previously known to be resistant was added to the four varieties above. Cuttings were graded into "rooted" and "unrooted" according to the amount of initial rooting present. Whereas all unrooted cuttings had no visible roots, the degree of rooting on the "rooted" cuttings varied with the variety. Thus AEE55 had very few roots and OJ47 and FF21 were little better, whilst OR55 and OM26 were well rooted. Half the cuttings in both "rooted" and "unrooted" grades were placed overnight in 5 p.p.m. solution of $\beta$-indolyl-butyric acid in water.

It was intended to have five replicates for each variety and treatment, but owing to shortage of material OJ47 was included in only three frames and FF21 in only two frames. OM26 was used to fill up in place of these varieties and so maintain uniform spacing. Two frames were planted on

TABLE II.

EFFECT OF GROWTH SUBSTANCE ON BASAL SHOOT CUTTINGS OF WILT-RESISTANT VARIETIES WITH AND WITHOUT INITIAL ROOTING.

MEAN PERCENTAGES OF SETS LIFTED, NOVEMBER, 1946.

| | OR55 | | AEE55 | | OM26 | | OJ47† | | FF21‡ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Good. | Small. | Good. | Small. | Good. | Small. | Good. | Small. | Good. | Small. |
| "Rooted" with growth substance .. .. | 22 | 8 | 22 | 12 | — | 2 | 7 | — | 40 | 5 |
| "Rooted" without growth substance .. | 22 | 6 | 20 | 14 | — | — | 20 | — | 35 | 5 |
| "Unrooted" with growth substance .. | — | 4 | 8 | 4 | 2 | — | 3 | 3 | 10 | 10 |
| "Unrooted" without growth substance .. | 2 | 2 | 4 | 14 | — | 2 | 13 | 3 | 20 | 20 |

† 3 replicates only. ‡ 2 replicates only.

23rd May and three on 7th June. The cuttings were lifted in November and graded. Table II shows the mean percentages of both good and small sets for each variety and treatment. Except for AEE55 relatively few small sets were produced.

* Varieties raised by Professor E. S. Salmon at Wye and shown to be resistant to Verticillium Wilt by Dr. W. G. Keyworth at East Malling.

Comparing first the five varieties in the frames in which they all occur, FF21 gave significantly more good sets than all the others. There were no significant differences between OJ47, AEE55 and OR55. OM26, however, despite a moderate take the previous season, was a complete failure. It is interesting to note that the *varietal* differences in take were not correlated with initial rooting, thus OR55 was generally " well rooted " and AEE55 " poorly rooted ", yet both gave similar takes ; while OM26 which was initially " well rooted " failed altogether. Nevertheless, *within a variety* the better rooted grades of cutting gave superior results, thus confirming the experience of 1945.

Only AEE55 and OR55 were available to give a good comparison of the growth substance treatments, but in neither was there any significant effect.

**Lateral Shoot Cuttings.**

The lateral cuttings were obtained in the same way as for the 1945 experiments and the two types of cuttings together with a parent shoot are illustrated in Fig. 2.

**Varietal response to growth substance treatment.**

The 1945 trials had showed that Fuggle " heel " type lateral cuttings were a general failure, with growth substance treatment hastening death. Cuttings of four wilt-resistant varieties all treated with a growth substance gave a fair take, but with these varieties there were no untreated controls. With the wilt-resistant varieties two types of lateral cuttings were used, and those made from the middle portion of laterals and cut to a node gave much better results than those made from the basal portion with a " heel " attached. Therefore, in the present trial, it was decided to use only the " nodal " type of cutting. In addition to untreated controls, cuttings were treated with 5 p.p.m. and 10 p.p.m. solutions of $\beta$-indolyl-butyric acid in water. Six varieties were included in the trial, Fuggle, Eastwell Golding, Bullion, OJ47, OR55 and FF21. Two frames were planted on 18th July and three on 20th July. Each variety and treatment occurred once in each frame. Only a few of the cuttings survived until lifting time early in November.

Although the total number of sets produced by the cuttings treated with $\beta$-indolyl-butyric acid at 10 p.p.m. was only about half that of the control or 5 p.p.m. solution, the difference was not large enough to be significant owing to the relatively large plot to plot variation. There were, however, varietal differences in the numbers of both good and useless sets produced, as is shown by the summary of the data in Tables III (a) and (b).

TABLE III.

VARIETAL DIFFERENCES IN PER CENT. TAKE OF LATERAL CUTTINGS.

(a) Good Plants.

| OJ47 | Fuggle. | OR55 | Bullion. | Eastwell. | FF21 | *Sign. Diff.* |
|---|---|---|---|---|---|---|
| 3·3 | 4·7 | 4·7 | 6·0 | 11·3 | 28·6 | 7·4 |

(b) Small Plants.

| OJ47 | OR55 | Eastwell. | Fuggle. | FF21 | Bullion. | *Sign. Diff.* |
|---|---|---|---|---|---|---|
| 1·3 | 1·3 | 3·3 | 3·3 | 6·7 | 13·3 | 6·9 |

FF21 produced very many more good sets than any other variety. It is worth considering the small sets as, had the months of August and September been more favourable, they might have developed into useful plants. Had this been so, Bullion would have greatly improved its performance, as this variety produced many small sets.

**The effect of different growth substances on two types of lateral cuttings.**

Bailey (1939) obtained good results from the use of certain growth substance with lateral cuttings, but the East Malling experiment (in 1945) with Fuggle indicated that treatment with one particular growth substance hastened death. In 1946, therefore, an experiment was planned to compare the kind and strength (treatments 3 and 4 below) of growth substance used by Bailey with those used in the East Malling trials. In addition, an alcoholic dip of $\beta$-indolyl-butyric acid was used at two strengths. The two types of lateral cutting (basal and nodal) of Eastwell Golding were used and were subjected to the following treatments.

1. $\beta$-indolyl-butyric acid 5 p.p.m.
2. ,, ,, ,, 10 p.p.m.

3. β-indolyl-acetic acid 100 p.p.m.
4. ,, ,, ,, 200 p.p.m.
5. β-indolyl-butyric acid dip 2·5 mg./c.c. in 50 per cent. alcohol.
6. ,, ,, ,, 5·0 mg./c.c. ,, ,, ,,

Controls soaked in plain water and dipped in 50 per cent. alcohol were also included.

Four frames each containing one plot of ten cuttings of each treatment were planted on 23rd and 24th July. By 26th August the harmful effect of certain treatments was apparent.

In the 100 and 200 p.p.m. β-indolyl-acetic acid and 2·5 mg./c.c. β-indolyl-butyric acid alcoholic dip treatments, there were no surviving cuttings, whilst only two worthless plants were left in the nodal type of cutting treated with 5·0 mg./c.c. alcoholic dip. The percentage take of the remaining four treatments is shown in Table IV. Apart from the obvious superiority of the nodal type of cuttings over the " heel " type, there were no significant differences. The trial has again shown that lateral cuttings can be rooted without the use of a growth substance, and that the use of the latter is of no benefit and may be very harmful if of unsuitable concentration.

TABLE IV.

EFFECT OF GROWTH SUBSTANCE TREATMENTS ON TWO TYPES OF LATERAL CUTTINGS.

| Type of cutting. | % Plants Produced. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Water Control. | | Alcohol Control. | | 5 p.p.m. β-indolyl-butyric acid. | | 10 p.p.m. β-indolyl-butyric acid. | | Mean. | |
| | Good. | Useless. | Good. | Useless. | Good. | Useless. | Good. | Useless. | Good. | Useless. |
| Heel.. .. .. | — | 2·5 | — | 5·0 | 2·5 | 2·5 | — | 2·6 | 0·63 | 3·1 |
| Nodal .. .. | 10·0 | 12·5 | 10·0 | 12·5 | 17·5 | 20·0 | 10·0 | 20·0 | 11·9 | 16·2 |

**Discussion.**

Although the account of both the 1945 and 1946 trials records many failures and therefore makes somewhat sad reading, the experiments have provided some very useful information from the practical point of view.

*Basal Shoot Cuttings.* Propagation by means of this type of cutting appears to be a practical proposition where suitable cold frames and labour are available. If good results are to be obtained it is necessary to pay attention to certain details. The parent hills should be lightly earthed up as growth starts in the spring. Earthing should not be done until growth has started, as if earthed up early in the season and the weather is then wet, the soil may become panned and the young shoots forced to grow out horizontally, appearing in a circle instead of from the crown of the hill. The shoots intended for cuttings should not be removed until there is some initial rooting on the blanched, below soil portion. The time needed for this initial rooting to take place may vary with variety, season and soil. In 1945, at East Malling, Eastwell Golding growing at Bradbourne showed initial rooting before Fuggle and Bullion growing in the main garden. In most seasons the shoots will have attained a length of 2-3 ft. before there is much initial rooting, therefore they should be carefully laid along the rows out of the way of the cultivators. In some types of wirework extra strings can easily be provided for the shoots. Treatment with a growth substance is not recommended. Though the effect of soaking overnight in a solution of β-indolyl-butyric acid at 5-10 p.p.m. in 1946 was not definitely harmful, as it was at 25 p.p.m. with Fuggle in 1945, there is no evidence that the treatments were beneficial. When applied in the form of an alcoholic dip in 1946, β-indolyl-butyric acid was very harmful. The results of the East Malling trials are not in agreement with those of Bailey, who found β-indolyl-acetic acid at 200 p.p.m. and phenyl-acetic acid at 500 p.p.m. beneficial. It must, however, be remembered that Bailey used much younger shoots (" asparagus " shoots) only a few inches high and raised the cuttings in pots in a frame in a cool greenhouse. Therefore, either the age of the cutting or the method of growing may have had an effect. This differential response to growth substance treatment is purely of scientific interest, as further practical work at Wye (reported by Beard and Wilson, 1946) caused the young asparagus type of shoot to be rejected in favour of more mature shoots with initial rooting without the aid of growth substances ; the East Malling experiments have given definite proof that untreated cuttings from these shoots root readily. Both years' trials indicated that soaking the cuttings overnight in plain water might possibly be beneficial. Further trial is needed to obtain definite information on this practical point. There is probably some varietal difference in ease of propagation as, in 1946, the initially well rooted OM26 was practically a complete failure ;

Fig. 1.

Basal shoot and cutting; note initial rooting.

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FIG. 2.

Lateral shoot and cuttings.

(a) " nodal " cutting ;
(b) " heel " cutting.

and, though not a failure in 1945, it gave the lowest take of any of the varieties tested. On the other hand, in 1946, FF21 gave much the best take of all varieties. The very definite superiority of Eastwell Golding over Fuggle, noted in 1946, may be due to difference in initial rooting and not any inherent varietal difference, particularly as very good takes were obtained with Fuggle cuttings in 1945.

*Lateral cuttings.* Even if a reasonably good take is obtained, this type of cutting is not such a satisfactory method of propagation as basal shoot cuttings. Plants formed from lateral cuttings are never sufficiently robust for planting out in the hop garden. They require to be grown on for a season in a nursery. The time taken to produce a useful plant is therefore the same as in the layering method (Beard, 1944) with the disadvantages of specialized equipment and fewer cuttings per parent plant. These trials have shown definitely that lateral cuttings are not likely to be a success when planted direct into simple cold frames. If it is desired to use this class of cutting, as when working up a stock from a very small nucleus and making use of all available material, then the cuttings should be coddled more by following a technique similar to that used by Bailey in his original experiments. The East Malling trials have shown the superiority of cuttings cut to a node in preference to the " heel " type originally used by Bailey. Our experiments do not support Bailey's observations that laterals cannot be rooted without the aid of a growth substance. With lateral cuttings there seems to be rather more evidence of varietal differences than with basal shoot cuttings and as with the basal shoot cuttings FF21 was definitely the best.

In both seasons weather conditions at the time of planting the cuttings and for about a week afterwards were very important. For example, in 1946, the first two frames in Trial I planted on 21st May gave a mean take of 56 per cent., whilst those planted on 4th June gave only 31 per cent. Similarly, the two frames of lateral cuttings planted on 23rd July (maximum temperature 75° F.) gave a mean take of 22 per cent., whilst the two planted the next day (maximum temperature 83° F.) had a take of 9 per cent.

**Acknowledgements.**

The writers wish to thank Dr. E. S. J. Hatcher of the Imperial College of Science and Technology for advice as to the kind and strengths of growth substances suitable for trial. Mr. S. C. Pearce arranged the layout of the trials and Mr. J. Taylor made statistical analyses of the data.

**Summary.**

An account is given of further trials in the propagation of hops by softwood cuttings. Two main types of cuttings were used, those made from basal shoots and those made from laterals. The trials with *basal shoot* cuttings confirmed the finding of the previous season that cuttings made from shoots with some initial rooting gave the best results, and that with all varieties treatment with a synthetic growth substance might be very harmful or at the best of little benefit. *Lateral* cuttings cut to a node were again superior to those with a " heel ", and the reaction to treatment with a growth substance was similar to that noted for basal shoot cuttings.

Whilst the use of basal shoot cuttings in simple cold frames is a practical proposition, lateral cuttings even of the superior nodal type give a very poor yield of useful material. If this type of cutting is used a more elaborate technique is needed.

References.

Bailey, C. R. (1939). " Some preliminary experiments in the use of root initiating substances in hop propagation." *J. S.-E. Agric. Coll.*, **44**, 47-53.

Beard, F. H. (1944). " Propagation Trials with Hops. I. The effect of treating cuttings (strap-cuts) with a growth substance before planting." *Rep. E. Malling Res. Sta. for 1943*, 68-70.

——— (1944). " The Intensive Propagation of Hops." *Rep. E. Malling Res. Sta. for 1943*, 112-4.

———, and Wilson, D. J. (1946). " Propagation Trials with Hops. II. Preliminary trials in propagation by softwood cuttings." *Rep. E. Malling Res. Sta. for 1945*, 96-103.

# PROPAGATION TRIALS WITH HOPS.

## V. FURTHER EXPERIMENTS IN TREATING CUTTINGS (STRAP-CUTS) WITH GROWTH SUBSTANCES

By F. H. BEARD and DOROTHY J. WILSON

### Introduction.

In earlier trials (Beard, 1944) soaking strap-cuttings of three varieties in a solution of α-naphthalene-acetic acid (20 p.p.m.) prior to planting was in two seasons mainly harmful. There were, however, varietal and seasonal differences. Thus, in the first season (1941-2) treatment significantly increased the take of Bullion and decreased the take of Fuggle, whilst the take of Brewer's Gold was slightly but not significantly increased. In the second season (1942-3) treatment reduced the take of all three varieties, though with Bullion the decrease was too small to be significant. In both seasons the treated cuttings were slower in showing shoot growth above ground. There were also varietal differences in forwardness of bine growth in April, Bullion being the most forward and Fuggle the most backward.

In the discussion of the results it was suggested that the varietal and seasonal differences in response to treatment might be due to differences in the physiological forwardness of the cuttings at the time of planting. Dr. E. S. J. Hatcher later suggested that possibly too strong a solution was used and that the complete immersion of the cuttings might also be harmful. In the season 1945-6 an experiment was planned to test whether any of these factors was responsible for the variable response. In addition a small trial was made to see if dipping the cuttings in an alcoholic solution of growth substance, a method successfully used with many types of hardwood cuttings, would be satisfactory with hops. The data obtained from these two trials are reviewed in the present paper.

### Main Experiment.

The varieties Fuggle and Bullion were chosen as representing the extreme differences of reaction to treatment noted in the earlier trials. Two growth substances, β-indolyl-butyric acid and α-naphthalene-acetic acid were used at strengths of 5 and 20 parts per million. Cuttings were treated with each solution in two ways, by total immersion and by partial immersion with only the bottom 2 in. of the cuttings covered by the solution. The cuttings were left overnight (about 18 hours) in the solutions prior to planting. Planting was done on four dates: 29th November, 1945, 10th January, 13th February, and 14th March, 1946, and sufficient cuttings were freshly cut from the parent hills for planting on each date. The experimental plots consisted of single rows of 10 cuttings planted 4 in. apart in the rows with guard cuttings at each end. There were four replicates of each treatment at each date of planting. The four blocks of each date of planting were randomized and the treatments randomized within these blocks. The whole trial occupied 4 rows each 2 ft. 6 in. apart.

In April, records were made on the forwardness of the cuttings as represented by the number showing growth above ground level and by the length of the most forward shoot. This record was made on all the 12 cuttings, including guards, in each plot. The sets were lifted, graded and weighed in November, 1946.

TABLE I.

MEAN NUMBER OF CUTTINGS OUT OF 12 SHOWING GROWTH AND MEAN LENGTH IN CM. OF LONGEST SHOOTS, APRIL, 1945.

| | Time 1. | | Time 2. | | Time 3. | | Time 4. | |
|---|---|---|---|---|---|---|---|---|
| | No. | Length. | No. | Length. | No. | Length. | No. | Length. |
| Fuggle .. .. | 10·6 | 10·8 | 11·1 | 14·4 | 10·0 | 9·8 | 6·9 | 4·5 |
| Bullion .. .. | 6·1 | 4·2 | 9·5 | 7·0 | 8·2 | 5·0 | 7·3 | 3·5 |
| Mean .. .. | 8·3 | 7·5 | 10·3 | 10·7 | 9·1 | 7·4 | 7·1 | 4·0 |

**Results.**

Generally a high percentage of cuttings in all treatments made shoot growth in April. However, the figures as summarized in Table I do show an effect of variety and time of planting. The means for both varieties show Time 2 to be the most forward and Time 4 the most backward. Taking the varieties separately, there are differences between them, though with both Time 2 is the most forward. With Fuggle, Time 4 is markedly the most backward. With Bullion, Time 1 has the fewest shoots above ground, and there is less difference in shoot length between the four dates of planting. Except for Time 4, Fuggle was markedly more forward than Bullion. With the exception of Time 1, the forwardness of the times of planting with Fuggle is what one might expect. The backwardness of Time 1 as compared with Time 2 may be attributed to the ground being " panned down " by the heavy December rains (4·15 in.) so that the cuttings had difficulty in breaking through. The very low number of shoots recorded for Time 1 in Bullion is probably accounted for by the incidence of Downy Mildew, which may also account for the relatively high number of shoots for Time 4. Bullion is a variety in which the " straps " may be attacked by Downy Mildew (*Pseudoperonospora humuli*). The disease is progressive during the plants' dormant season, so that cuttings infected with the disease may have been included among those planted at Time 1, whereas as the planting times got later it was possible to reject more affected cuts (owing to their being discoloured) before planting. At the last planting it is likely that few infected cuts would have been planted. Analysis of the data for number of growing cuttings showed differences due to growth substance treatment (Table II). The effect of the treatments is complex and the figures do not show a high degree of significance, but they give indications that α-naphthalene-acetic acid (mean 8·25) retarded shoot growth more than β -indolyl-acetic acid (mean 9·15) and that in this respect the stronger solutions (mean 8·35) had more effect than the weaker (mean 9·0).

Table II.

Effect of Growth Substance Treatments on Forwardness of Shoots.

| | Number of growing cuttings out of 12 in April. | | | |
|---|---|---|---|---|
| | α-naphthalene-acetic. | | β-indolyl-butyric. | |
| | 5 p.p.m. | 20 p.p.m. | 5 p.p.m. | 20 p.p.m. |
| Partial immersion .. .. | 8·7 | 8·3 | 9·5 | 8·9 |
| Total immersion .. .. | 8·8 | 7·2 | 9·1 | 9·0 |

The sets were lifted in November, the guard plants discarded and the remainder graded into good sets fit for planting out and " smalls ", which included those suitable for rebedding and those that were entirely useless. Very few " smalls " were produced in any plot and in considering the results they may be ignored.

Statistical examination of the data relating to the number of good sets produced showed that whilst the growth substance treatments had no effect, both variety and time of planting did have an effect (Table III).

Table III.

Effect of Variety and Time of Planting on Number of Good Sets Produced.

| | Mean number of Good Sets out of 10. | | |
|---|---|---|---|
| | Fuggle. | Bullion. | Difference. |
| Time 1 .. | 9·7 | 7·0 | 2·7 |
| Time 2 .. | 9·3 | 7·2 | 2·1 |
| Time 3 .. | 9·2 | 7·2 | 2·0 |
| Time 4 .. | 8·6 | 8·4 | 0·2 |

(figures bracketted do not differ significantly)

It will be seen that Fuggle gave a significantly higher take than Bullion at the first three planting times, whilst at Time 4 they were about equal. Fuggle maintained a good take of over 90 per cent. for the first three dates of planting with a slight drop to 86 per cent. for Time 4. Bullion Hop maintained a take of around 70 per cent. for the three first planting dates with a rise to 84 per cent. for the last planting. This difference between the behaviour of the two varieties when planted early and late may be due to the reasons given in considering forwardness of growth in April (i.e. Downy Mildew).

Table IV gives a summary of the mean weights of the good sets for the two varieties and four dates of planting.

TABLE IV.

EFFECT OF VARIETY AND TIME OF PLANTING ON SIZE OF SETS PRODUCED.

| Mean weight of 100 good sets. | | | |
|---|---|---|---|
| Time. | Fuggle. lb. | Time. | Bullion. lb. |
| 4 | 2·2 | 3 | 1·7 |
| 1 | 2·3 | 4 | 1·9 |
| 3 | 2·4 | 2 | 1·9 |
| 2 | 2·6 | 1 | 2·2 |

(figures in brackets do not differ significantly)

It will be seen that though there were big differences in weight between the two varieties, there was little difference due to time of planting. It is interesting to see that Bullion produced smaller as well as fewer sets, though the natural tendency is for a lower take to give larger sets owing to the wider spacing of the cuttings (see p. 140 of this Report).

**Secondary Trial.**

The layout of this was similar to the main trial, but occupied one row only. Fuggle was included, but, owing to the shortage of material, Brewer's Gold had to be substituted for Bullion. The solution used was 5 mg. $\beta$-indolyl-butyric acid per c.c. in 50 per cent. alcohol. Planting was done on the same dates as in the main trial. At each date four plots of treated and untreated cuttings of both varieties were planted, the base of each treated cutting being quickly dipped into the solution just before planting. Records were similar to those on the main trial. Growth records in April showed no differences in forwardness due to variety or treatment, but did show that there were differences due to time of planting. In order of forwardness they were Times 2, 3, 1 and 4, the last being the most backward. When the sets were lifted in November it was found that all plots had produced a very high percentage of good sets (nearly half the plots giving 100 per cent) and there were no differences connected with variety or any treatment. However, small but significant differences were found in weight of sets. Time 1 gave the smallest sets and whilst there was no significant difference between Times 2 and 3 or between Times 3 and 4, Time 4 sets were significantly smaller than those of Time 2.

**Discussion.**

These trials have shown that the variable results previously obtained by treating cuttings with a growth substance cannot be attributed to the method of application, time of planting or strength of solutions used. Whilst the somewhat unusual reaction of " strap-cuts " (also softwood cuttings) is a matter of interest to the plant physiologist, from the practical point of view it may safely be said that treatment of hop cuttings with a growth substance is unlikely to be beneficial and may under certain conditions (which are not yet known) be definitely harmful. The present trials have shown that the effect of time of planting the cuttings is worthy of further investigation. Fuggle gave a better " take " if planted before March, but different results might be obtained in other seasons. Bullion gave the opposite results, possibly because of the incidence of Downy Mildew. It is interesting to note also that in the present trial Fuggle was more forward in growth in April than Bullion Hop, whilst in the earlier trials the position was reversed.

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The writers are indebted to Dr. E. S. J. Hatcher of the Imperial College of Science and Technology for much helpful advice on the use of growth substances. The layout of the trials was designed by Mr. S. C. Pearce and Mr. J. Taylor made statistical analyses of the data.

**Summary.**

An account is given of two trials in which hop cuttings (strap-cuts) were treated with synthetic growth substances before planting.

The main trial was designed with a view to ascertaining if the variable results previously recorded were due to strength of solution, method of application or time of planting. A small trial was also made to see if the " alcoholic dip " method of treatment, which has been found satisfactory for many types of hardwood cuttings, was suitable for hops.

Apart from some checking effect on early shoot growth noted in the main trial, the various growth substance treatments had no effect. Time of planting affected forwardness of growth, when measured in April, number and weight of sets produced. There were varietal differences in response to the time factor.

## Reference.

Beard, F. H. (1944). " Propagation Trials with Hops. I. The effect of treating cuttings (strap-cuts) with a growth substance before planting." *Rep. E. Malling Res. Sta. for 1943,* 68-70.

# PROPAGATION TRIALS WITH HOPS

## VI. THE EFFECT OF SPACING CUTTINGS (STRAP CUTS) IN THE NURSERY ROWS ON THE NUMBER AND SIZE OF SETS PRODUCED

By F. H. BEARD

### Introduction.

With the present demand for large quantities of healthy material for replacing diseased and worn out gardens it is desirable to obtain the best possible take from cuttings planted in the nursery. The spacing of the strap-cuttings in the nursery rows is one of a number of factors which may influence both the number and size of sets* produced. In the Research Station nurseries cuttings are normally planted about 4 in. apart in rows 2 ft. 6 in. apart. Though this spacing has proved reasonably satisfactory in practice, it was thought desirable to have some definite information as to the effect of spacing. It is not practicable to have the rows closer than 2 ft. 6 in., otherwise lateral growth will reach from row to row, making cultivations and spraying difficult, if not impossible, after about midsummer. It also seems likely that this inter-row spacing gives reasonable room for a season's root growth. However, the spacing of cuttings in the rows may be varied considerably and thus affect the number and size of sets produced. Three spacings were compared in the seasons 1944-45 and 1945-46 and the results are described in this paper.

### Description of the Trials.

In each trial 10 randomized plots of each spacing distance were planted in one long row. A guard cutting was planted between plots. The plots were 9 ft. long and contained 12, 18 or 36 cuttings according to the spacing. Owing to the shortage of material it was not possible to use the same variety in both seasons. The two varieties used, Fuggle and the Seedling OH44 were chosen as they normally give a very good take at East Malling and would therefore be more likely to show the effect of variation in spacing than varieties giving a poor take. In each season the sets were lifted and graded in November. Two grades were made: (1) *good sets*, fit for planting out, and (2) *small sets*, some of these could be grown on in a nursery for a season if worth while, but others were useless. The good sets were weighed as well as counted.

TABLE I.

COMPARISON OF EFFECT OF SPACING ON PERCENTAGE TAKE, SIZE AND NUMBER OF SETS PRODUCED PER ACRE.

| | 1944-45 (Fuggle). | | | | 1945-46 (OH44). | | | |
|---|---|---|---|---|---|---|---|---|
| Spacing. | % smalls. | % good sets. | wt. of 100 good sets. lb. | good sets per acre. | % smalls. | % good sets. | wt. of 100 good sets. lb. | good sets per acre. |
| 3-in. | 9·2 | 79·7 | 14 | 55,563 | 7·2 | 80·7 | 18 | 55,752 |
| 6-in. | 8·9 | 82·8 | 19 | 28,849 | 2·2 | 88·9 | 21 | 31,696 |
| 9-in. | 2·5 | 88·3 | 21 | 20,521 | 1·7 | 83·3 | 26 | 19,554 |

### Results.

The numbers and weights of sets are summarized in Table I. In both seasons a very good take was obtained with all three spacings. The take including both grades was never less than about 84 per cent. and in three instances was over 90 per cent. In the first season there was a steady and significant increase in the percentage of good sets with increased spacing, but in the second, although spacing at 6 inches gave a significantly higher proportion of good sets than at 3 inches, this was not so at 9 inches. It is difficult to account for this, but it is possible that attack by wireworms might have had something to do with it. With the wider spacing there were fewer plants per square yard to act as hosts for the wireworms and thus a heavier infestation of individual plants. The fact that there was also a lower percentage of small sets, that is, cuttings tended either to die or to make good sets,

* 1-year-old rooted plants.

lends support to this theory. Though wider spacing produced a higher percentage of good sets, the 3-inch spacing gave by far the most good sets per acre of nursery ground. The size of sets, as measured by their weight, increased with wider spacing. This increase in size is greater than indicated, as the larger the set the greater the part left in the ground at lifting.

**Discussion.**

It appears that, with rows 2 ft. 6 in. apart, close planting of the cuttings in the rows will give a good take and produce the maximum number of good sets from a given area of nursery bed. When the supply of cuttings is ample, they should be planted about 3 inches apart, but when the supply of cuttings is very limited (i.e. when working up a new variety from a few parent hills), spacing should be increased to 6 inches in order to obtain the most good sets from the available material.

Although the size of set is increased by wider spacing, there does not seem to be any great advantage in producing extra large sets. Relatively small sets, as long as they are healthy, appear to do just as well as the larger ones when planted out in the hop garden. This may be because they are less mutilated in lifting and have proportionately more root. Large sets may command a higher market price, but the increase would have to be substantial to compensate for the fewer sets produced per acre of nursery.

**Acknowledgements.**

The layout of the trials was designed by Mr. S. C. Pearce and Miss D. J. Wilson assisted in the planting and recording of the 1945-6 trial.

**Summary.**

A trial of three distances of spacing cuttings (strap-cuts) in the nursery rows showed that, whilst the percentage take and size of sets increased with wider spacing, the greatest number of useful sets per acre of nursery was produced by close planting.

# MOSAIC DISEASE OF THE HOP

## A STUDY OF TOLERANT AND SENSITIVE VARIETIES

By W. G. KEYWORTH

### Introduction.

Mosaic disease of the hop was first described in detail by Salmon (1923*a*), after a preliminary account in the previous year of the disease in the experimental garden at the East Malling Research Station (Salmon, 1922). It is probable that the disease had been known for many years before that time, however, under the name of " False Nettlehead " (Duffield, 1925). In his description of the disease at East Malling, Salmon reported the existence of seedling varieties bred by him which showed no symptoms, although they were growing among other varieties displaying mosaic. Male hops in the same garden could be similarly grouped into those showing mosaic and those with no symptoms.

Salmon (1923*b*) described a severe attack of mosaic in a commercial garden of the Tutsham variety, the affected plants being confined to an area surrounding a row of the new seedling variety M45. As the M45 plants showed no symptoms, Salmon suggested that they were acting as carriers of the disease, which was being transmitted to the neighbouring Tutshams.

Mosaic was first shown to be graft transmissible by Thrupp (1927) who also demonstrated that apparently normal plants of the variety M45 could transmit the disease to Tutshams. His work was followed by the extensive studies of Mackenzie *et al.* (1929) on a wide range of varieties from Germany, Denmark, America and England. They determined the reaction to mosaic of many commercial varieties from these countries and also of certain Wye Seedlings and male hops. It was found that all the tested varieties could be grouped into one of two well-defined categories—(*a*) Those readily displaying symptoms (now termed *mosaic-sensitive* varieties), and (*b*) those capable of carrying the disease without showing symptoms (now termed *mosaic-tolerant* varieties). The English Golding hops, Golding varieties and certain male varieties were shown to be mosaic-sensitive and the varieties Fuggle, Colgate, Allcorn and certain males were found to be mosaic-tolerant.* It was concluded that the mosaic-tolerant varieties were a potential source of danger to the mosaic-sensitive Goldings. Writing of the Fuggle, Colgate and Tolhurst varieties, Salmon and Ware (1932*a*) later suggested that the danger of planting these varieties near to Goldings was less than when Wye Seedling varieties were so planted, although they gave no evidence for this suggestion.

As already reported by the writer (Keyworth, 1943), mosaic disease had become of considerable importance in the years preceding 1942 in certain hop growing areas, notably the Teme Valley district of Worcestershire. For this reason among others, there had been an increasing tendency, in this area in particular, to replace the mosaic-sensitive but reputedly high quality Golding hops by the mosaic-tolerant Fuggle variety. It thus seemed advisable to study the potential danger to the Golding hops arising from the planting of this and other tolerant varieties, including male hops.

The present investigation was, therefore, started in 1942 : (1) To determine the proportion and distribution of mosaic carrier plants in commercial Fuggle gardens. (2) To observe the effects of planting Fuggles and Goldings in proximity in commercial gardens. (3) To select mosaic-sensitive and tolerant male varieties as a prelude to the raising of clones of such males for planting in commercial gardens. (4) To determine the reaction to mosaic disease of a number of Wye Seedling varieties.

### Experimental Methods.

Tests of the selected plants were carried out by the method of inarch grafting developed by previous workers and already described by the writer (Keyworth and Davies, 1946). Plants suspected of carrying mosaic were grafted to mosaic-sensitive Golding hops and plants under test for mosaic sensitivity to known carrier plants of one of the Wye Seedling varieties.

All the grafting work was carried out in a glasshouse using young plants grown from cuttings in five-inch " Long Tom " pots. Symptoms were recorded in the glasshouse during the first season and any indicator plants not showing mosaic were then planted out of doors for a further symptom record in the next year.

* Of these tolerant varieties the only one now grown extensively is the Fuggle which occupies about 75 per cent. of the present hop acreage.

**Survey of Commercial Fuggles for Mosaic Carrier Plants.**

Two hop growing areas were selected for this survey. In one, the Weald of Kent, the acreage is almost exclusively devoted to the Fuggle variety ; in the other, the Teme Valley district of Worcestershire, both Fuggles and Goldings are grown.

*The Weald of Kent.*

Thirty-two farms were chosen in this area, their distribution being illustrated in the map (Fig. 1). Three widely separated hills were selected in one Fuggle garden on each farm and one cutting taken from each hill. The 96 cuttings were planted in pots in the glasshouse and one bine from each inarched with one bine from a young Rodmersham Golding plant, these Goldings being grown from cuttings taken from the East Malling mosaic-free clonal stock. One ungrafted control Golding plant was included for every three grafted plants.

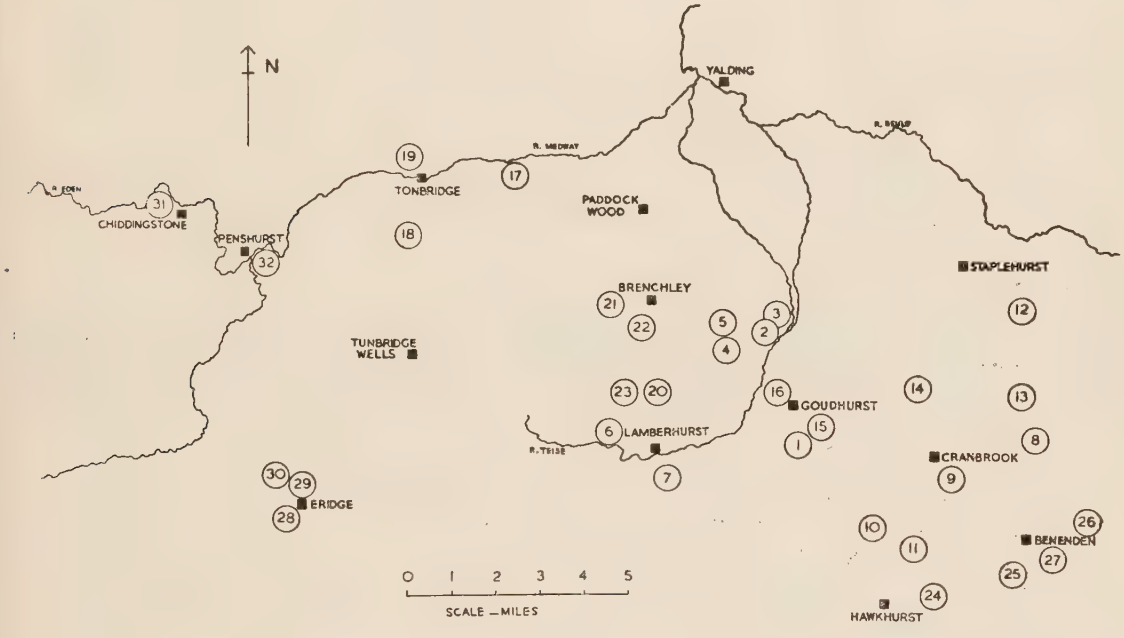


FIG. 1.

Distribution of farms in the Weald Fuggle survey.

The first symptoms were noted on the Golding indicators from five to six weeks after the grafts were made. At this time a slight but definite vein clearing could be seen on the third to seventh fully opened leaves. This vein clearing was usually confined to short lengths of the finer veins and at first it was not regarded as a definite symptom. The plants showing this early symptom, however, invariably developed the more characteristic symptoms of stunting and leaf distortion later, although no plant showed in the glasshouse the extreme downward curl and dark green mottling which are so characteristic of the disease in the field. These symptoms were clearly shown in the second year, however, on the infected plants removed out of doors for observation. It thus appears that the vein clearing symptom is a reliable indicator of the presence of mosaic in plants inarched in the glasshouse.

The symptom records on the Golding indicators are given in Table I. None of the 32 control plants showed symptoms.

Thus at least 78 of the 92 grafted Fuggle plants were mosaic carriers. All the test plants from 22 of the farms were carriers and from only one farm were plants obtained none of which transmitted the disease to Goldings.

TABLE I.

RECORD OF MOSAIC TRANSMISSIONS FROM FUGGLE PLANTS (WEALD) TO GOLDINGS.

| Farm. | Successful grafts. | Mosaic transmissions. | Farm. | Successful grafts. | Mosaic transmissions. |
|---|---|---|---|---|---|
| 1 | 3 | 3 | 17 | 3 | 3 |
| 2 | 3 | 2 | 18 | 2 | 1 |
| 3 | 3 | 0 | 19 | 3 | 3 |
| 4 | 3 | 1 | 20 | 3 | 3 |
| 5 | 3 | 3 | 21 | 3 | 3 |
| 6 | 2 | 2 | 22 | 3 | 2 |
| 7 | 3 | 3 | 23 | 3 | 3 |
| 8 | 3 | 3 | 24 | 3 | 3 |
| 9 | 3 | 3 | 25 | 3 | 3 |
| 10 | 3 | 3 | 26 | 3 | 3 |
| 11 | 3 | 3 | 27 | 3 | 3 |
| 12 | 3 | 1 | 28 | 2 | 2 |
| 13 | 3 | 3 | 29 | 3 | 3 |
| 14 | 3 | 2 | 30 | 3 | 3 |
| 15 | 3 | 1 | 31 | 2 | 2 |
| 16 | 3 | 2 | 32 | 3 | 3 |

Total Successful Grafts 92. Total Transmissions 78.*

* Including 4 plants showing symptoms in 1943, but not in 1942.

*The Teme Valley.*

Fuggle cuttings were collected by the farmers from twelve farms scattered throughout the district (see Map—Fig. 2) and sent by post to the Research Station. Cuttings were taken from several gardens on some of the larger farms. The number of test plants from some of the farms was thus greater than in the Weald survey, but the number of farms was less.

FIG. 2.

Distribution of farms in the Teme Valley (Worcs.) Fuggle survey.

The grafting tests were made in the same way and at the same time as those on the Weald Fuggles. The results are given in Table II. None of the 24 control plants showed symptoms.

TABLE II.

RECORD OF MOSAIC TRANSMISSIONS FROM FUGGLE PLANTS (WORCESTERSHIRE) TO GOLDINGS.

| Farm. | Successful grafts. | Mosaic transmissions. |
|---|---|---|
| 1 | 3 | 3 |
| 2 | 6 | 2 |
| 3 | 2 | 1 |
| 4 | 13 | 10 |
| 5 | 3 | 2 |
| 6 | 3 | 3 |
| 7 | 4 | 3 |
| 8 | 6 | 6 |
| 9 | 9 | 9 |
| 10 | 2 | 2 |
| 11 | 6 | 3 |
| 12 | 4 | 3 |
| Totals | 61 | 47 |

Thus at least 47 of the 61 grafted Fuggle plants from the Teme Valley were mosaic carriers, a somewhat similar proportion to that found among the Weald Fuggles. Carrier plants were obtained from every farm although not all the plants from every garden transmitted the disease to Goldings.

It is possible that the absence of symptoms from some of the indicator Golding plants was due to causes other than absence of virus in the corresponding test Fuggle plants (e.g. failure of the virus to pass across the graft union or prolonged masking of symptoms in the indicator). The exact proportion of virus-free Fuggles in the two samples cannot therefore be assessed. It is clear, however, that the proportion of mosaic carrier Fuggle plants in each area was at least 80 per cent., and that these carriers were widely distributed.

It seems likely, therefore, that the variety has been extensively infected for many years, possibly since shortly after it was first introduced in 1875. In this connection it is of interest to note that Mackenzie *et al.* (*loc. cit.*) reported that plants of the older variety Colgate were mosaic carriers.

**Field Observations.**

Mosaic incidence in Golding gardens planted next to Fuggles was studied on several farms. In every case the Fuggles and Goldings had been grown in proximity for several years and no information was available on the original health of the Golding stock. It was thus necessary to deduce the effect of any infection from the Fuggles by the distribution and amount of disease present in the Goldings at the time of observation. The following are three representative cases.

*Farm No. 1. Shelsley, Worcestershire.* A Golding garden on this farm had shown some mosaic in the years 1930-40. In 1940 the practice was started of replacing the grubbed mosaic Golding plants with Fuggles. When observed in 1942 at least 50 per cent. of the remaining Goldings showed mosaic symptoms and the grower reported a greatly increased spread of the disease in the years 1940-42.

*Farm No. 2. Chilham, Kent.* On this farm a block of Canterbury Goldings had been growing for at least ten years next to Fuggles, being separated by a 12 ft. broad alley. When observed in 1942 the Goldings contained 16 per cent. of mosaic affected plants. These were fairly evenly scattered throughout the Goldings, but with some concentration toward the Fuggles. There was, of course, no direct evidence of spread, but it appeared likely that the Fuggles were acting as a source of infection. The amount of disease present in the Goldings formed a marked contrast to that seen in Farm 3 (below).

*Farm No. 3. Canterbury, Kent.* On this farm, which was located about three miles from farm No. 2, Goldings and Fuggles had been grown in proximity for about fifteen years, here also being separated by a 12 ft. broad alley. A preliminary inspection of the Goldings showed that very little mosaic was present and the case was therefore studied in detail.

A mosaic record in the Goldings made in 1943 showed that only 23 of the 1,077 plants were affected, these diseased plants being scattered throughout the Goldings. A further record in 1944 gave 25 newly-infected plants, similarly scattered, the young plants put in place of the mosaic plants removed in 1943 being healthy (Fig. 3).

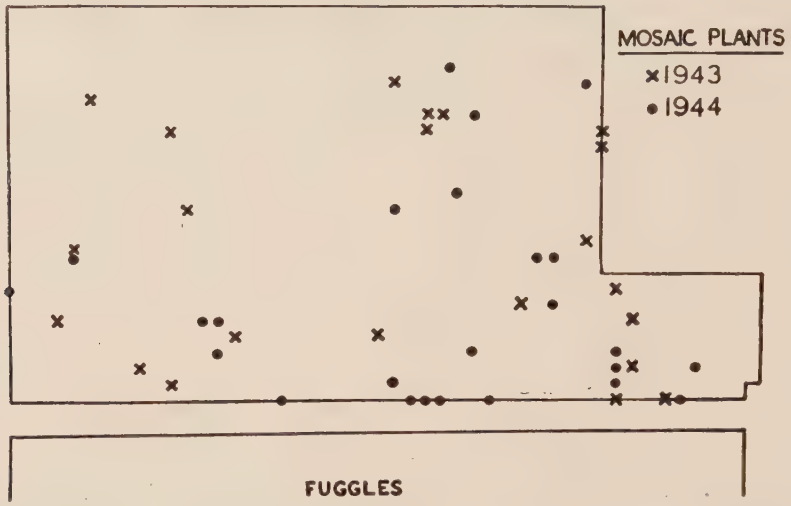


Fig. 3.

Incidence of mosaic disease in 1943-4 in Goldings growing adjacent to Fuggles on Farm No. 3.

In order to determine whether the Fuggles were mosaic carriers and the Goldings reacted normally to graft infection, cuttings were collected in 1943 from both the Fuggles and Goldings for grafting tests. The cuttings were taken from every fifth plant on both sides of the broad alley separating the Fuggles and Goldings and from similarly spaced Golding and Fuggle plants seven hills in from the broad alley. The following tests were then made on the young plants grown from these cuttings :

1. The Goldings were grafted to known carrier plants.
2. The Fuggles were grafted to known mosaic-sensitive Goldings from another source.
3. The Fuggles were grafted to their opposite Goldings.

Results are given in Table III.

Table III.

| Test. | No. of successful grafts. | No. of Goldings showing mosaic. |
|---|---|---|
| Goldings inarched to known carrier plants .. .. .. .. | 12 | 11 |
| Fuggles inarched to known mosaic sensitive Goldings .. .. .. | 14 | 13 |
| Opposite Fuggles and Goldings inarched | 10 | 8 |

These results indicate that :—

1. The Goldings in the garden displayed mosaic symptoms after graft inoculation.
2. The Fuggles contained a high proportion of mosaic carrier plants.
3. The Fuggles could transmit the disease to the Goldings by grafting.

It thus appeared that in this garden mosaic-carrier Fuggles and mosaic-sensitive Goldings were growing in proximity without any considerable spread of mosaic from the Fuggles to the Goldings.

**The Adjacent Planting Of Fuggles and Goldings—Discussion.**

As already mentioned, Salmon and Ware (1932) suggested that there was less danger of Goldings contracting mosaic disease from adjacent Fuggles than from adjacent Wye seedling varieties.

The results of the present survey of commercial Fuggles for mosaic carrier plants demonstrate that there is a very high proportion of such plants in commercial gardens in two hop growing areas. It

should be noted, however, that the tests were carried out by grafting and that the mode of spread of mosaic in the field is unknown, nor is any information available on the homogeneity of the disease. Thus, although a grafting test may demonstrate that a plant is carrying mosaic disease, such a test provides no indication of the likelihood of this carried disease infecting nearby mosaic sensitive plants.

The study of commercial plantations in which Goldings and Fuggles were growing adjacently, however, showed that in some gardens Goldings next to Fuggles were heavily infected with mosaic whereas in others the infection was only slight. There is thus some evidence that the non-infection of Goldings from nearby Fuggles in some cases may be connected with causes as yet not understood (such as, *e.g.* the natural vector) and not solely with the variety of tolerant plant involved. This matter clearly requires further study, but in the meantime it is obviously advisable that growers should be warned of the possible danger of planting Fuggles and Goldings in proximity.

**The Selection of Mosaic Sensitive and Tolerant Male Varieties.**

The hop is dioecious and the cones, which constitute the crop, are produced only on the female plants. In order to ensure partial pollination with a resultant increase in crop weight, it is the practice in British hop fields to plant males, in the proportion of one male plant to every 100-200 female plants. No recognized varieties of male plants have been propagated commercially, although some growers have selected types of suitable flowering season to pollinate early, mid-season and late female varieties. Mackenzie *et al.* (*loc. cit.*) suggested that male plants in Golding gardens might be mosaic carriers and thus serve as centres of infection. A survey by the writer of such gardens in the West Midland area gave strong evidence that this was the case (see Fig. 4) and emphasized the need for the propagation of mosaic-sensitive males which could safely be planted among Goldings. Similarly, it appeared advisable to select mosaic-tolerant male varieties which could be planted among tolerant commercial hops without succumbing to the disease.

For the reasons given above each male plant in a commercial garden had to be regarded as an individual. Owing to the common practice of putting two or more plants to a hill it was doubtful whether even the cuttings taken from one hill could be regarded in general as clonal but, as in this investigation only gardens with one plant per hill were used, all the cuttings from a hill were regarded as homogeneous.

Two gardens containing mosaic-tolerant female varieties and two containing mosaic-sensitive female varieties were selected and all the cuttings collected from several male plants of different flowering season in each garden. Some five or six cuttings were obtained from each hill. The method of testing was as follows :—

One or more cuttings from each hill were inarched to mosaic-sensitive Golding hops in order to test whether they were carrying mosaic disease. Other cuttings were inarched to known carrier plants of the Wye variety OO63 in order to determine whether they displayed mosaic symptoms and could thus be classed as sensitive. The remaining cuttings were grown for propagation.

By this method three mosaic-sensitive male varieties and three mosaic-tolerant male varieties of different flowering seasons were selected for further propagation.

During the course of this study it was found that the progeny of one of the male plants in one of the Golding gardens were mosaic carriers. The Goldings in this garden near to the parent male plant were therefore inspected in the two subsequent years, but no infected hills were seen, and it thus appears that the disease was not spreading from this male plant.

**The Testing of Wye Seedling Varieties.**

As already described, Salmon (1922) has reported that the varieties originally bred by him included some showing mosaic symptoms and others remaining free from symptoms. The mosaic disease in the former (sensitive) varieties eventually became so widespread—due to the adjacent planting of tolerant varieties—that an automatic selection took place and only the tolerant varieties survived. For this reason, all the Wye varieties now in commercial use are tolerant and it is possible that all the plants of these varieties are mosaic-carriers.

Early segregation of varieties has been possible in the more recent breeding work at Wye and a number of varieties have been selected by Salmon as possibly mosaic-sensitive and thus suitable for planting near Goldings. The criterion of mosaic sensitivity used by Salmon has been the display of symptoms by one or more plants in the nursery—a method which he regarded as unsatisfactory owing to the danger of infection of the remaining plants of the variety. At his suggestion, therefore, tests were made in the glasshouse at East Malling of a few of these later selections, using the methods already described for testing male hops, largely in order to determine whether some routine test of new varieties for mosaic reaction was practicable.

Sufficient cuttings were available of most varieties to graft from four to six plants to Goldings and a similar number to known carrier plants.

The results of the tests are given in Table IV.

TABLE IV.

TESTING OF NEW VARIETIES FOR MOSAIC REACTION.

| Variety. | Test plants inarched to Goldings. | | Test plants inarched to known carriers. | | Classification of Variety. |
|---|---|---|---|---|---|
| | No. of plants. | No. of Goldings showing mosaic. | No. of plants. | No. of test plants showing mosaic. | |
| OF27 .. | 4 | 0 | 1 | 1 | Mosaic sensitive ? |
| WFF28 .. | 5 | 0 | 4 | 3 | Mosaic sensitive. |
| WFA111 .. | 5 | 0 | 3 | 3 | ,, ,, |
| OR76 .. | 5 | 0 | 4 | 3 | ,, ,, |
| 413a .. | 6 | 6 | 6 | 0 | Mosaic tolerant. |
| WFF12 .. | 5 | 5 | 4 | 0 | ,, ,, |
| AOO1 .. | 5 | 5 | 6 | 0 | ,, ,, |
| 1147* .. | 5 | 4 | 6 | 0 | ,, ,, |
| WFB26 .. | 5 | 4 | 5 | 2? | Mosaic tolerant ? |

* This variety is not a Wye seedling. It was bred on a commercial farm and was included in these tests as it had shown resistance to Verticillium Wilt. It was necessary to determine its reaction to mosaic disease before planting in commercial gardens.

These results demonstrate that the varieties WFF28, WFA111 and OR76 are mosaic-sensitive and 413*a*, WFF12, AOO1 and 1147 are mosaic-tolerant. Owing to the fact that only one OF27 plant was successfully grafted to a carrier plant the evidence that this is a mosaic-sensitive variety is not conclusive. The appearance of possible symptoms in plants of the variety WFB26 appears anomalous as the grafts to Goldings suggest it to be a tolerant variety. The variety may react in a similar fashion to mosaic infection as certain other Wye seedlings which, as reported by Salmon and Ware (1932*b*), occasionally display symptoms although normally appearing tolerant. This phenomenon requires further study.

It appears from these results that the methods described would provide a practicable means for the routine testing of new seedlings for mosaic sensitivity or tolerance.

**Summary.**

An account is given of a study of the incidence of mosaic-carrier plants in commercial plantations of the Fuggle variety of hop and of observations on the incidence of mosaic disease in Golding hops planted near to Fuggles. The methods of testing the mosaic reaction of male hops and certain new seedlings are also described.

REFERENCES.

DUFFIELD, C. A. W. (1925). "Nettlehead in Hops." *Ann. appl. Biol.*, **12**, 536-43.

KEYWORTH, W. G. (1943). "Diseases of the Hop." *J. Inst. Brewing*, **49**, 128-35.

———, and DAVIES, D. L. G. D. (1946). "Nettlehead disease of Hop (*Humulus lupulus*)." *J. Pomol.*, **22**, 134-9.

MACKENZIE, D., *et al.* (1929). "The Mosaic disease of the Hop. Grafting experiments. II." *Ann. appl. Biol.*, **16**, 359-81.

SALMON, E. S. (1922). "Fifth report on the trial of New Varieties of Hops." Publ. E. Malling Res. Sta.

——— (1923*a*). "The 'Mosaic' disease of the Hop." *J. Min. Agric.*, **29**, 927-34.

——— (1923*b*). "Sixth report on the trial of New Varieties of Hops." Publ. E. Malling Res. Sta.

———, and WARE, W. M. (1932*a*). "Report from the Mycological Department." *J. S.-E. Agric. Coll.*, **29**, 15-22.

———, and ——— (1932*b*). "The Chlorotic disease of the Hop." *Ann. appl. Biol.*, **19**, 518-28.

THRUPP, T. C. (1927). "The Transmission of 'Mosaic' disease in Hops by means of Grafting." *Ann. appl. Biol.*, **14**, 175-80.

Fig. 4.

Mosaic-carrier male plant in the centre of a severe mosaic area in a Golding garden (most of the affected Goldings have been grubbed).

[*face p.* 148

# Section IV

# *BULLETINS FOR FRUITGROWERS*

## PROGRESS IN STRAWBERRY CULTURE*

By W. S. ROGERS

The strawberry occupies a unique position among our fruits, for not only is it the quickest cropping, and earliest in season, but it can be eaten with little or no sugar, and it is as rich in vitamin C as oranges and lemons.

Considerable progress in strawberry culture has been made as the result of scientific research and practical experience. The importance of planting good stocks has been shown to be largely a matter of freedom from disease, especially yellow edge and severe crinkle, which between them often limit the life of a plantation. New information is also available on other diseases and pests.

The greatest advance in providing a supply of virus-free plants has been the Strawberry Nuclear ocks Scheme followed by the Special Stock certificate. These virus-tested clones of Royal Sovereign alling 40, Huxley M.44 and Oberschlesien M.42 raised in complete isolation can be relied on to give ood results if suitably protected from reinfection. The importance of planting virus-sensitive arieties, such as Sovereign, well away from virus-tolerant varieties, such as Huxley, has been amply emonstrated. What is not so commonly recognized is that it is most desirable to plant healthy olerants, such as Huxley M.44, as far away as possible from old infected beds of any variety, for various iruses can accumulate in Huxleys until final breakdown occurs. Even a few yards isolation from ld plants is better than none.

### Virus Infection.

It is courting disaster to raise runners in crowded areas of infection. Special Stock runners are the best to plant. Special Stock plants " once grown " well away from strawberry areas should also be excellent, but similar plants once grown in crowded areas are almost certain to have received a lot of virus infection. This situation is likely to persist until we can get perfect control of the strawberry aphid.

The use of the isolated block system of runner laying is an essential part of the Special Stock scheme, for it is necessary to allow effective inspection and roguing of plants. It is sometimes suggested that runners raised in this way may be overcrowded and too small for best results, but this is based on a mistaken idea. Experiments have shown that health, not size of runner, is the most important factor, provided the runner is big enough to get properly established. A crown the thickness of a pencil and roots 2 in. long are a reasonable minimum standard ; and isolated block plants, properly managed, should well exceed this standard. The only case where it may be worth while to select the larger (and earlier) runners is where it is intended to leave them to fruit the first year ; for in the maiden year the larger plants will produce a slightly larger yield. This is a doubtful asset, however, for any fruit taken in the maiden year is more than lost from the second year's crop, when compared with plants deblossomed in the first year. A paper describing recent improvements in the isolated block system appears elsewhere in this Report.

### Other Troubles.

A disease of considerable importance in the Wisbech area and several other areas is verticillium ilt. This disease is being studied by the East Malling pathologists, but at present it seems to depend ore on seasonal and soil conditions than on infection in the runner beds. A look-out should also e kept for the red core root rot, caused by *Phytophthora fragariae*. Dr. Hickman is still working t this disease, and it seems as if it may be closely associated with excess soil moisture at certain asons. This disease has had very serious results in Lanarkshire, the Tamar Valley and Hampshire. t would appear undesirable to introduce runners from infected beds to clean areas. Certain varieties such as those bred at Auchincruive are resistant to this disease.

As routine pest and disease control measures, nicotine dipping of the runners before planting is very desirable, or warm water treatment if mite is present. DDT dust provides a very useful

* From a lecture given in the Wisbech area.

new weapon which can be used in May to control capsid, rhynchites and strawberry blossom weevil. It may, if desired, be mixed with the routine sulphur dust.

Certain cultural measures can considerably increase cropping. Relatively close spacing of plants or the " matted row " system provides more crowns per acre, and this may increase crop under certain conditions. Any treatment which improves the soil moisture conditions such as irrigation or improving the humus content of the soil is likely to increase crop. Keeping the water in the dykes not too far below the surface during the fruiting season should be worth trying in this respect.

With regard to frost, varieties whose blossoms were sheltered by the leaves, such as Huxley, have been shown to be less liable to frost damage than varieties whose blossoms project beyond the leaves. On the other hand, any insulating layer such as weeds or straw placed between the warm earth and the blossoms keeps the heat of the earth away from the blossoms on a frosty night and renders them more liable to damage. It has been demonstrated experimentally at East Malling that it is desirable to delay strawing until all danger of frost is past.

**Varieties.**

With regard to varieties an analysis of the acreage of certified strawberry runners in 1946 shows that Huxley, with 652 acres, comprised 76 per cent. of the total, a large increase on 1945. This is not surprising in view of the fixed price policy. Nevertheless, it would be worth while to increase the area of Royal Sovereign in suitable areas, for the acreage of Sovereign plants certified in 1946 was only 15 per cent. of the total. Of other varieties, Madame Lefebvre provided 3·2 per cent., Early Cambridge 1·4 per cent., Perle de Prague 1·3 per cent., Tardive 0·9 per cent., and Oberschlesien 0·8 per cent. Potential new Special Stocks of Madame Lefebvre, Early Cambridge and Perle de Prague are under test at East Malling, and also several promising new varieties such as Auchincruive No. 9.

The most important points are : To treat runner raising as a special business. Keep sensitives isolated from tolerants and young from old plantings. Use Special Stocks wherever possible, or once-grown plants raised from Special Stocks in isolation. Given these, and reasonable care in pest and disease control, good results should be obtainable.

**Summary.**

Recent research and practical experience show the importance of treating runner raising as a special business, keeping virus-sensitive varieties isolated from tolerants, and young from old plantings. The use of special stocks or once-grown special stock progeny is advocated. The trend of planting, as shown by acreages of certified runners of different varieties, is discussed.

# THE STRAWBERRY RHYNCHITES AND ITS CONTROL

By G. H. L. DICKER

During recent years many strawberry growers, especially in South-East England, have suffered serious losses through the depredations of a small weevil known as the Strawberry Rhynchites (*Rhynchites germanicus*). Locally it is also called the Elephant Beetle, a very descriptive name derived from the long snout possessed by the insect, but unfortunately also liable to cause confusion for another strawberry pest, the Strawberry Blossom Weevil (*Anthonomus rubi*) or Needle Bug as it is called in Hampshire, has been known by the same name for a much longer time. As both insects are often present on the plants together it is necessary for the grower to distinguish one from the other. Inspection under a hand lens will show the Rhynchites to be metallic, blue-green with a square body (Fig. 1) whilst the Blossom Weevil is black and oval in shape (Fig. 2); both have long snouts

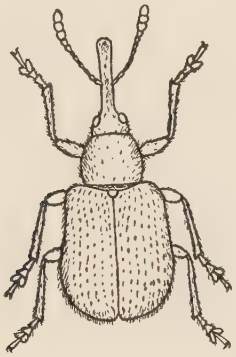

FIG. 1.
The Strawberry Rhynchites.

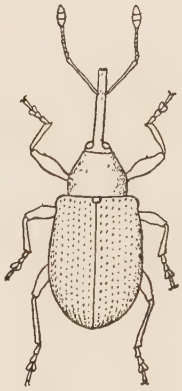

FIG. 2.
The Strawberry Blossom Weevil.

and measure $\frac{1}{4}$ inch in length. Each insect also causes a distinctive type of damage, easily recognized even if the culprit is not present; the Rhynchites attacks the stalks of young leaves and blossom trusses and the tips of stolons by girdling them with a ring of punctures which causes wilting and finally death of the entire portion above the girdle; the Blossom Weevil attacks only individual blossom buds, making a single puncture in the blossom stalk so that the bud droops, dries up and falls off.

Besides strawberry, both insects attack many forms of *Rubus* including blackberry, loganberry, phenomenal berry and raspberry; the Rhynchites most often girdles the tips of young canes, causing branching, and on blackberry severs the terminal portions of blossom trusses whilst they are still in the grape stage; the Blossom Weevil again confines its activities to the blossom buds.

## Life History.

Sufficient should already have been said for the grower to recognize the Strawberry Rhynchites and the following remarks will apply only to this pest. Adults first appear during March or early April and numbers continue to increase until early May when emergence is complete. The first weevils to arrive on the plants live between the unfolding leaflets of young leaves and feed by nibbling small holes in the laminae. In normal seasons numbers have increased considerably by mid-April when a careful survey of the plants will usually indicate a few leaves have already begun to wilt due to feeding punctures in the stems. At this period weevils are often found in pairs, especially on the leaf-stalks. During sunny weather many bask on the older leaves, but as soon as conditions become unfavourable little activity occurs, most of the insects descending to the crowns where they seek shelter. This insect is very shy indeed and at the slightest provocation falls to the ground where it remains motionless until danger is past; it is, therefore, advisable to work up-sun when searching for the Strawberry Rhynchites, for even a shadow falling on the plant is often enough to make it loose its hold.

Eggs are laid in the stalks of young leaves and blossom trusses and later near the tips of stolons. The female first bores a small hole, then excavates a larger internal cavity with her rostrum or snout, at the tip of which the mouth is situated. She then reverses her position and by means of an extrusible ovipositor places an egg in the prepared cavity. Up to four eggs are found in a stem and, in addition, many feeding punctures. As soon as the full complement of eggs has been laid she moves down the stalk and makes a ring of punctures beneath the lowest egg ; this causes wilting of the injured portion which later shrivels and falls to the ground. As a rule eggs are first found during the third week in April, but much depends upon the prevailing weather conditions ; a more reliable guide is the condition of the plant—during the past three years eggs have first been found at the time the earliest blossom trusses were appearing through the crowns of the varieties Royal Sovereign and Lefebvre.

On hatching the white, legless grub burrows in the dried-up portion of leaf or blossom truss cut off by the parent when the egg was laid. Strangely enough it finds sufficient sustenance in this desiccated tissue to complete its development and when fully fed enters the soil where a small cocoon is constructed. Within a week or two the chrysalis stage appears and a few weeks later another transformation produces the adult beetle. Newly formed beetles can be found in their earthen cells from late July onwards, but do not emerge until the following spring ; throughout this period they remain quiescent, neither feeding nor showing any signs of activity.

**Economic Importance.**

The habit of girdling stems of leaves and especially blossom trusses makes this insect an important pest ; moreover, the period of maximum infestation occurs at the time when blossom trusses are appearing. Surveys of strawberry plots in the Kingswood area of Kent, in 1945, showed that often 50 per cent. of the blossoms were destroyed and in extreme cases, by the end of May, plants possessed only a peripheral ring of old leaves, all the young growth having been destroyed.

On cultivated blackberry considerable damage is caused to the blossom trusses whilst they are still in the grape stage. Only the apical portion is severed, but as these buds produce the earliest ripening fruits the loss can be serious. On other forms of *Rubus* the attack is mainly concentrated near the tips of young canes where the growing point is killed and branching results, making training more difficult.

**Control.**

From life history studies the following points emerge which have a direct bearing on control measures :—

(1) No injury of importance is caused until egg laying begins.

(2) Eggs are first found about the time the earliest blossom trusses are pushing through the crowns of the varieties Royal Sovereign and Lefebvre, i.e. approximately the third week in April.

(3) Adults continue to emerge from their winter quarters until early May.

This valuable information indicates that control measures should first be applied when egg laying begins, but as fresh weevils will be appearing for at least another fortnight more than one application may be necessary unless an insecticide is employed which will persist over this length of time.

Preliminary laboratory trials gave promising results. When weevils were treated with dusts containing 3 per cent. and 5 per cent. DDT, a complete kill was obtained ; even at a strength of 1 per cent. over 90 per cent. died. Benzene hexachloride (of which the toxic element is commonly called " Gammexane ") was not so effective, a 3 per cent. dust giving a kill of 50 per cent.

By the time laboratory results were available, in 1945, the attack had reached an advanced stage in the field. It will be remembered this was an early season with growth some two weeks in advance of normal years. On 21st April all the plants on a small-holding at Kingswood, Kent (comprising ½ acre of Lefebvre, Tardive and Huxley) were dusted with 3 per cent. DDT at the rate of 24 lb. per acre. Before treatment weevils were numerous and could be found on almost every plant. Two days after dusting a few live weevils were found, but thereafter none until 8th May, whilst on neighbouring plots the attack continued to be severe. This indicated that one application of a 3 per cent. DDT dust could give protection from this pest for at least a fortnight.

The same holding was used in 1946, separate plots being dusted with 3 per cent. and 5 per cent. DDT and 5 per cent. benzene hexachloride ("Gammexane") on 20th April when eggs were first found and the variety Lefebvre had one blossom truss just appearing ; 20-23 lb. per acre were applied by a hand-operated machine. Results, set forth in the table, were assessed by inspecting plants for

damage, and illustrate how effectively both concentrations of DDT controlled the Strawberry Rhynchites during the two weeks following treatment.

| Treatment. | % plants damaged. | |
|---|---|---|
| | 3rd May. | 17th May. |
| 3% DDT. .. .. .. | 1 | 4 |
| 5% DDT. .. .. .. | 1 | 0 |
| 5% Benzene hexachloride .. | 18 | 27 |
| Control .. .. .. | 21 | 29 |

Even at the end of a month there was no sign of injury to the plot receiving 5 per cent. DDT, and very little where 3 per cent. DDT was used. Benzene hexachloride proved disappointing; the figures suggest that this insecticide may give temporary control, but does not persist in toxic form long enough for one application to give adequate control.

**Recommendations.**

From the results of trials in 1945 and 1946 a 3 per cent. DDT dust can be recommended to control the Strawberry Rhynchites. Provided the following directions are followed success should be achieved on strawberries with one application.

(1) Dust as soon as the first blossom truss is visible, during the latter half of April.

(2) Concentrate on getting the dust into the crowns of the plants, for it is here that the weevils spend most of their time. Best results will be obtained by dusting each row separately.

(3) The experimental results were obtained by using 20-24 lb. per acre. For commercial treatment 28 lb. per acre should be allowed.

On cultivated blackberry the treatment should be carried out immediately damage is noticed to the tips of young blossom trusses, usually early in May.

The Rhynchites will continue to attack the tips of raspberry and loganberry canes until August. Whilst no reports have yet been received of this injury being economic on a field scale it often causes anxiety to gardeners. A dust should be applied whenever the damage is considered to merit treatment.

Earlier, mention was made of the Strawberry Blossom Weevil. Hey* has reported good results against this pest on loganberry with 5 per cent. DDT dust, two applications being made during the latter half of April. At present more information is required on the period when the Blossom Weevil emerges from hibernation; preliminary investigations by the writer indicate that it appears somewhat later than the Rhynchites and trials have shown it is less susceptible to DDT, a 5 per cent. dust being necessary to obtain a good kill. Where this pest is known to be present on strawberry in addition to the Rhynchites it is advisable to use 5 per cent. DDT dust, making the first application at the time recommended for Rhynchites and repeat 10-14 days later.

**Summary.**

The life history and damage caused by the Strawberry Rhynchites are described in popular form.

In field experiments excellent control was obtained on strawberries by applying 3 per cent. DDT dust when the first blossom trusses appeared. A dust containing 5 per cent. benzene hexachloride was much less effective.

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# FAILURE OF APPLE AND PEAR TREES TO CROP

By A. C. PAINTER

In the course of a year quite a number of enquiries are received from amateur growers asking why their apple or pear trees have failed to crop. It is therefore thought that a useful purpose can be served by setting out some of the commoner causes. These can be considered under two headings :

(1) Where the tree blossoms, but fails to mature a crop.

(2) Where the tree fails to blossom or only blossoms poorly.

**(1) Where the Tree Blossoms, but fails to mature a crop.**

**Lack of proper pollination.** To set a satisfactory crop the flowers of most kinds of apples and pears require to be pollinated with the pollen of another variety. This variety must produce good pollen and be in flower at approximately the same time as the one that it is desired to pollinate ; with pears the problem is complicated by a few cases of pollen " incompatibility ". Suitable varieties must therefore be chosen for planting together. The principles underlying pollination and a list of varieties that will pollinate one another are to be found in a pamphlet entitled *The Fertility Rules in Fruit Planting*, published by the John Innes Horticultural Institution, 31 Mostyn Road, London, S.W.19, price 6d.

**Frost and cold winds.** Frost and cold winds will sometimes do considerable damage at blossoming time.

When planting, care should always be taken to avoid frost pockets and, as far as possible, situations where the trees will be unduly exposed to cold winds in the spring. If this is not altogether possible then the next best thing is to plant relatively frost resistant or late blossoming varieties. The apples Ellison's Orange, James Grieve and Worcester Pearmain come in the first category and Edward VII, Orleans' Reinette and Crawley Beauty in the second.

The amateur grower with only a few small trees in his garden may be able to provide some form of cover protection on frosty nights while his trees are in bloom, but this is not a practical proposition where the trees are large or there is an appreciable number of them.

**Scab.** If the trees are badly attacked by Scab a considerable dropping of small fruitlets often results.

Though Scab can be reduced, especially in gardens, by cutting out and burning scabbed wood before the end of March, and collecting and burning or burying the leaves soon after they have fallen, the only effective method of controlling it is by means of spraying. Two pre-blossom sprays, usually with lime-sulphur, are necessary, the first at the green-cluster and the second at the pink-bud stage at strengths of 2½ and 2 per cent. respectively, followed by a post-blossom application at petal fall of 1 per cent. In wet years further spraying may be necessary. Full instructions can be found in Ministry of Agriculture Advisory Leaflet No. 245, *Apple and Pear Scab.**

**Sawfly.** If there is only a light set of fruit and there is a bad infestation of sawfly, it may result in most of the young fruitlets falling. Where the set is heavy, sufficient fruitlets usually remain to give a crop.

The damage is done by the grub of the sawfly and can be recognized by the appearance in June of brown frass on the young fruit. Fruits so attacked usually drop whilst they are still quite small. It must not be confused with Codling caterpillar damage which comes later in the season. The best control is a nicotine wash at petal fall, which can be included in the post-blossom Scab spray. Details of this pest and of the way to control it are given in Ministry of Agriculture Advisory Leaflet No. 13, *Apple Sawfly.**

**Apple Sucker.** Though now rarely met with in commercial plantations, the apple sucker can, especially in the West Country, be a serious pest in gardens and small holdings where steps are not taken to control it, and is capable of causing complete crop failure. Both the flower buds and blossom stems are attacked, as a result of which the buds may die without opening, or, if they do expand, fail to set fruit. The blossom trusses often remain on the tree dead and brown as if damaged by frost. This is a characteristic sign of attack. It can also be recognized by the small white, often irridescent, drops of sticky fluid excreted by the insects.

* Obtainable from Ministry of Agriculture and Fisheries, Government Buildings (Block C), Lytham St. Anne's, Lancashire.

This can best be controlled by a tar oil wash in the winter, or, failing that, a nicotine or other contact insecticide spray applied during the period between the opening of the leaf buds and the bursting of the blossom. Full particulars can be found in Ministry of Agriculture Advisory Leaflet No. 96, *Apple Sucker.**

**(2) Where the Tree Fails to Blossom or only Blossoms Poorly.**

**Too vigorous growth.** A tree that is growing over vigorously will usually either produce little blossom, or, if it does blossom, the blossom frequently fails to set. This can be due to a variety of causes, such as :

(*a*) The tree being on a vigorous rootstock, in which case it may take seven, eight or more years to settle down and start cropping. If early cropping is desired a tree must be grown on a dwarfing stock.

(*b*) Too severe pruning.

(*c*) Over manuring.

Where trees are showing signs of excessive vigour they should only be lightly pruned, and nitrogenous manures withheld for a time, though light dressings of potash should be given if available.

Judicious root pruning, bark ringing, and grassing down are methods sometimes used to check over-vigorous trees and bring them into cropping. Both root pruning and bark ringing must, however, be used with caution. Root pruning is carried out in winter and consists of digging a circular trench part of the way (usually half way) round the tree, and from 2 to 4 feet from it according to its age, and severing the main roots from the stem. Another part of the tree can be done the following year.

Bark ringing involves the removal of a ring of bark, down to the wood, from round the trunk about blossoming time. The width of the ring must be adjusted to the age and size of the tree and should be kept as narrow as possible ; in no case should it be more than $\frac{1}{4}$ to $\frac{1}{2}$ inch wide. The wound should be covered immediately with several turns of adhesive tape to encourage healing and prevent the entry of fungus diseases, and insect pests such as Woolly Aphid.

**Scion Rooting.** It sometimes happens that a tree on a dwarfing stock (which might be expected to crop early in its life) has been planted with the union below soil level, or the union becomes covered later on. The scion variety is then likely to form roots of its own with the result that the dwarfing effect of the stock may be lost, the tree becomes vigorous, and fails to crop. Where this has not gone too far it can be checked by unearthing and severing the scion roots.

Scion rooting can be prevented by planting the tree in the first place so that the union is 3 to 4 inches above soil level, and then seeing that it does not get covered as time goes by.

**Biennial Bearing.** In extreme cases of biennial bearing a tree may bear a heavy crop one year and little or nothing the next. Though much research work has been done on the subject no satisfactory way of curing this state of affairs has yet been evolved. There are, however, two things that can be done which will frequently help to counteract the tendency to some extent.

(*a*) *Pruning.* Before an " off " year reduce all established spur systems, leaving only one bud for each ; it is a good practice to leave equal numbers with strong buds and weak buds respectively. One-year-old laterals and leaders should be shortened so as to leave them 2 in. to 3 in. long, and a number of branches dehorned, possibly one out of every four, choosing the tallest ones. The dehorned branches should be distributed evenly about the tree. This aims at effecting a plentiful supply of young shoots and a reduction in the supply of blossoms that would normally be formed.

Before an " on " year, to provide bearing wood for the following season, the one-year-old wood should be left unpruned save for any necessary leader tipping and the removal of shoots that cause rubbing or much shading to neighbouring shoots. To prevent excessive blossoming all branched spur systems should be reduced to leave only one bud on each, except where the tree is already making very vigorous growth, in which case a less severe reduction should be made. Of the spur blossoms that remain after this treatment, two out of every three blossom trusses should be removed at time of flowering or the blossom buds should be pushed out by hand at the time of pruning. This latter treatment is often known as " bud rubbing ". All blossoms on one-year-old wood should be removed at blossom time.

The above recommendations apply to trees with pronounced biennial tendencies. When the biennial tendency shows signs of lessening, the severity of the treatments should be correspondingly reduced.

The principles underlying these recommendations are discussed more fully in Ministry of Agriculture Bulletin No. 133, *Apples and Pears*, pages 59 and 60.

* Obtainable from Ministry of Agriculture and Fisheries, Government Buildings (Block C), Lytham St. Anne's, Lancashire.

(*b*) *Fruit Thinning.* It has been found that fruit thinning will in many cases help to counteract the biennial tendency. Fairly drastic thinning, e.g. spacing the fruit to 6 inches or more apart according to the crop and variety, is likely to be more effective than light thinning, and early thinning than late thinning. It is usually necessary to continue the thinning over a number of years.

**Spray damage.** Spray, especially lime sulphur and summer petroleum, will cause fruit drop under certain conditions. Tar Oil, Petroleum Oil or D.N.C. wash applied too late in the dormant season may do damage to the fruit buds and prevent them developing.

Sprays should always be obtained from reliable sources and the maker's instructions carefully followed.

**Summary.**

The commoner causes of failure of apple and pear trees to crop in amateurs' gardens are discussed : (*a*) where the tree blossoms, but fails to mature a crop, and (*b*) where the tree produces little or no blossom.

# NOTES ON VARIETIES OF HOP RESISTANT TO VERTICILLIUM WILT

By W. G. KEYWORTH

Some 220 commercial and Wye Seedling varieties of hop have been tested since 1939 for resistance to Verticillium Wilt. None of the commercial varieties showed satisfactory resistance, but a number of Wye Seedlings and one variety bred on a commercial farm proved to be resistant, both in preliminary tests and further trials in commercial gardens. The results to date from some of these experiments are reported elsewhere (Keyworth, 1947), but as they are still in progress it is not yet possible to assess the resistance of any variety completely. Sufficient evidence has been obtained, however, to classify three of the varieties as " very resistant " and four as " moderately resistant ". All the varieties are mosaic-carriers.

Notes on the information now available on the brewing and cultural qualities of these seven varieties are given for the information of growers and others. With the exception of one variety (1147), details of crop, preservative value and season are abstracted from the annual reports by Salmon (1940*b* and 1941-45) and the information on brewing value is taken from the publications of various quoted authors. The writer has also included some notes of observations made by him in the course of the resistance trials.

An attempt has been made by the writer to give his opinion on the cultural suitability of each variety for replanting wilt areas. It must be emphasized however, that these opinions are provisional and based on a few years' experience only. For this reason, any reader who is especially interested in the varieties is advised to consult the publications by Professor Salmon and others, a list of which is appended.

The writer would like to take this opportunity of expressing his thanks to Professor Salmon for his help and encouragement throughout the whole of the work on wilt resistance.

Owing to the small size of the initial stocks and the demands of the experiments, there are, at present, no sets of the wilt resistant varieties available for distribution. It is hoped, however, by means of intensive propagation, to raise sufficient stock in the near future to give every grower with a severe wilt outbreak an opportunity to test some of the varieties on his own farm. In the meantime small plots of all the varieties except 1147 are available for inspection at the Research Station.

## A.—Very Resistant Varieties.

The wilt incidence in these varieties on severely affected ground has normally been from 2-4 per cent. (compared with 90-100 per cent. on the Fuggle control plants). There are indications, however, that they may show more disease on some sites than on others.

**OB53 (Nonsuch Hop).** (Second generation from a wild hop obtained from Manitoba, Canada.)
*Crop.* 5-year average—13¾ cwt. per acre.
*Preservative value.* 5-year average—10α = 86.
*Season.* Late.

This variety was described in 1940 (Salmon, 1940*a*), and in certain years has proved to be the richest hop in the world for soft resins content. Ford (1936) and Ford and Fletcher (1940) report very favourably on the variety in brewing tests, both as a copper hop or for dry hopping, and suggest that the quantity of hops used could with advantage be reduced proportionate to the P.V. Thompson and Brown (1945) report similarly on the variety. Records of the yield at East Malling during the past five years show the variety to be a low cropper. Even with a close-planted row, equivalent to 1,778 hills per acre, the crop has rarely exceeded an equivalent of 14 cwt. per acre, but the resistance trials have given some evidence that the variety may yield better on heavy soil. The variety has proved very erratic in performance, however, some bines bearing a heavy crop and others being almost barren, and it appears rather susceptible to Mould (*Sphaerotheca humuli*). Because of its high resistance the variety may be acceptable to those growers whose gardens are severely affected by wilt until some equally resistant, but higher cropping variety has been bred.

**OM26.** (Second generation from a wild hop obtained from Manitoba, Canada.)
*Crop.* 2-year average—13½ cwt. per acre.
*Preservative value.* 5-year average—10α = 103.
*Season.* Late.

This hop is closely similar to OB53, but differs from it in having a consistently higher preservative value. Salmon (1944) reports this to be so for the tenth consecutive season and considers the variety is a " bud sport " of OB53. Brewing reports by Ford and Fletcher (1940) are favourable and similar to those for OB53, but Thompson and Brown (1945) report the flavour of the beer to be " too bitter " at the hop rate used.

Fewer resistance trials have been conducted with this variety than with OB53, but it appears to be similar in resistance and cultural characters.

**AEE55.** (Second generation from a wild hop obtained from Manitoba, Canada.)
*Crop.* 3-year average—9¾ cwt. per acre.
*Preservative value.* (1942)—10α = 79.
*Season.* Late.

Thompson and Brown (1945) report favourably on the results of brewing tests with this variety. Cultural characters, however, are not good. As will be noted, the crop at East Malling is low, and in the resistance trials the bines have tended to fall away from the strings, necessitating special training late in the season. Although the cones are compact and very full of lupulin they are generally small and difficult to pick. It therefore seems unlikely that this variety will be acceptable to growers.

**B.—Moderately Resistant Varieties.**

The wilt incidence in these varieties on severely affected ground has been very variable, but is usually from 10-20 per cent. The percentage of wilt has been considerably less however on ground in which the " wilt-potential " of the soil has been somewhat reduced by fallowing, and this practice would therefore seem advisable before any attempt is made to reclaim wilt areas by planting these varieties.

**OR55.** (Second generation from New Mexican hop.)
*Crop.* 5-year average—20¾ cwt. per acre.
*Preservative value.* 4-year average—10α = 71.
*Season.* Late mid-season.

Thompson and Brown (1945) report that, from the results of two years' laboratory brewing trials, this variety was classified as " acceptable to the brewer ". The opinion as to palate in 1943 was " fairly good flavour " and in 1944 " normal mild bitter ".

The crop weights at East Malling have been consistently satisfactory. The cones are large and easy to pick and the variety has attracted favourable comment from many growers who have seen it in the trials. It appears likely to prove of commercial value and, although its resistance is not so high as that of some of the other selected varieties it is, in the opinion of the writer, the best all-round hop obtained to date in the resistance trials.

**OJ47.** (Second generation from New Mexican Hop.)
*Crop.* 5-year average—20½ cwt. per acre.
*Preservative value.* 2-year average—10α = 74.
*Season.* Early-Mid-season.

Thompson and Brown (1945) report that in one laboratory brewing test this variety produced a beer of " pleasant hop flavour ".

As the variety was selected in 1944 only a little information is available on its resistance under commercial conditions, but it seems likely to prove similar to OR55 in this respect.

The crop weights at East Malling have been consistently good, and the cones are large, though occasionally leafy and slightly subject to aphid attack. The variety appears of commercial promise and, in the opinion of the writer, may provide a very useful early resistant variety.

**219.** (First generation from New Mexican Hop.)
*Crop.* 5-year average—22¾ cwt. per acre.
*Preservative value.* 2-year average—10α = 62.
*Season.* Very late.

Ford and Fletcher (1940) report on the results of trials with the 1938 crop of this variety carried out in November, 1938, and November, 1939. In 1938, copper hop tests at 18·2 oz. per barrel gave " Quite a fair beer—slightly harsh bitter ", but the variety was not considered satisfactory as a dry hopper (2 oz. per barrel). A blend in the copper test of 6·2 oz. with 10 oz. control gave a " very satisfactory " beer. In the 1939 copper tests, however, the beers were unsatisfactory. Thompson and Brown (1945) state that in one test the beer had a " strong and unpleasant " flavour although they did not test the variety in blends. They regard it as of doubtful brewing value.

The variety has grown well in the resistance trials, but is very subject to Downy Mildew. Its very late cropping season is also a disadvantage, but it may prove acceptable to some growers.

**1147.** (Bred on a commercial farm—reputedly from Bates' Brewer.)
*Crop.* Approximately 15 cwt. per acre.
*Preservative value.* (1944)—10α = 43.
*Season.* Late.

This hop has been grown for many years on the commercial farm in Kent on which it was raised. Thompson and Brown (1945) report it to give a beer of a " pleasant mild flavour ". Although of only moderate cropping power, it appears to be otherwise quite acceptable.

**Summary.**

Notes are given of observations by other workers and by the writer on the brewing and cultura characters of seven varieties of hop which have shown some resistance to Verticillium Wilt. Of these the varieties OR55 and OJ47 appear likely to be the most generally acceptable.

## References.

Ford, J. S. (1936). " Brewing trials with New Varieties of Hops from East Malling Research Station and Wye College, Kent." *J. Inst. Brewing*, **42**, 352-3.

———, and Fletcher, L. (1940). " Brewing trials with New Varieties of Hops." *J. Inst. Brewing*, **46**, 243-5.

Keyworth, W. G. (1947). " Verticillium Wilt of the Hop (*Humulus lupulus*). II. The selection of wilt resistant varieties." *J. Pomol.*, **23**, in the press.

Salmon, E. S. (1940*a*). " Notes on Hops : 1940." Publ. S.-E. Agric. Coll., Wye.

——— (1940*b*). " Twenty-fourth report on the trial of New Varieties of Hops." Publ. E. Malling Res. Sta.

——— (1941-45). " Twenty-fifth to twenty-ninth reports on the trial of New Varieties of Hops." Publ. E. Malling Res. Sta.

Thompson, L. C., and Brown, B. M. (1945). " Laboratory brewing trials with Varieties of Hops, showing some Resistance to Verticillium Wilt." *J. Inst. Brewing*, **51**, 39-40.

# GROWING WALNUTS IN ENGLAND

By ELIZABETH M. GLENN

Practically all the older Walnut trees in this country are seedlings, and it is perhaps sufficient commentary to add that hardly 1 per cent. of them produce nuts comparable in quality or appearance with the nuts imported from the Continent or the United States.

Walnuts do not come true from seed and it is impossible to foretell when trees so raised will come into cropping, or the quantity or quality of the nuts they are likely to produce. The only way of being able to tell the future performance of the tree with any degree of certainty is to raise known varieties by budding or grafting.

**Propagation.**

Work on Walnuts, started at East Malling in 1925, soon showed that the budding or grafting of Walnuts out of doors was far too chancy in this climate to be relied upon as a means of raising young trees.

**Grafting.** The method found most successful in this country is to graft young rootstocks in pots under glass in February or March. Outdoor grafting can only be done successfully where the mean temperature from May to September is above 65° F.

Practically all the edible Walnuts grown in this country are varieties of *Juglans regia*. For these the rootstocks most commonly used are one or two-year-old seedlings of *Juglans regia* or *Juglans nigra*.

The seedlings, which should have a diameter at ground level of approximately ¾ inch, are lifted from the open ground in November and potted into deep 4½-inch pots (Long Toms). If the tap root is very long and cannot be fitted into the pot, even by twisting, it may be cut shorter rather than bruise the roots. When potting, the stock should be planted so that about 1½ inches of the main root, which was underground in the seed-bed, is exposed above the rim of the pot. The pots are placed in a cold frame and kept there until February, precautions being taken to protect them in frosty weather. They are then moved into the Propagation House and kept at a temperature of 60° to 65° F. They are ready for grafting two to three weeks later.

These seedlings are often very variable in vigour, even when all the seed nuts have been obtained from a single tree. With the object of obtaining more uniform rootstocks, experiments have been started on vegetative propagation. Stoolbeds of several species and hybrids are being grown, and layering experiments have given over 50 per cent. rooted shoots from some selections. It is too early however, to make definite recommendations.

It is of great importance to obtain good sound scion wood. Sturdy one-year-old shoots, 12 to 18 inches long, with as little pith as possible should be chosen. If suitable one-year-old shoots are not available, two or even three-year-old wood can be used successfully. The scions should be taken from the trees before the end of January ; if this is done later the parent trees may bleed profusely. The scions should be placed in damp sphagnum moss and stored in a cool frost-free place until required.

Grafting begins towards the end of February, the double tongue method being employed. The scion should be about 4 inches long with two or three good buds. Cuts should be made as shown at A, B, C, and D of Fig. 1 so as to form a double tongue at the base. The stock is cut down at the same time to within about 2 inches of the level of the soil in the pot so that the scion can be inserted in the top portion of the main root ; this ensures that the tree will not sucker in later years. The stock is first of all cut with a sloping cut as shown at E. Two vertical incisions are then made in the cut surface, one at the base and the other at the top as at F, and G and the scion inserted—J, so that the cambium layer, i.e. the layer between the wood and the bark, of stock and scion is in contact on at least one side. The graft is then tied firmly with string (raffia is not used as it rots too quickly), and all exposed cut surfaces and the tie over the part of the scion in contact with the stock waxed over in the usual way.

The grafted plants are then placed in a closed frame with a bottom heat of 70° to 75° F. ; union should be complete in about a fortnight. Union can also be obtained, although more slowly, if the plants are left on the open bench in a temperature of 65° to 70° F. It is important to avoid extreme fluctuations of temperature. Provided the scion wood, rootstocks and environmental conditions are good, this method should give anything from a 60 to an 80 per cent take.

The plants are hardened off slowly, and can be planted out in the open ground in June. The following year growths of from 1 to 2 feet may be expected, according to variety. The trees are usually

kept in the nursery until they reach a height of at least 4 or 5 feet, when they are transplanted to their permanent position.

This method of raising a tree is costly, but, as the life of a tree may be 200 years or more, during which it should not only produce a valuable crop, but at the end provide timber of considerable value, it can hardly be considered excessive.

**Patch-Budding.** An alternative method of propagation is patch-budding. This can be done in the open from the end of May to the end of July. Its success, however, depends very much on the season. In a hot summer a fairly good take may be obtained, but in a year with little sun very few

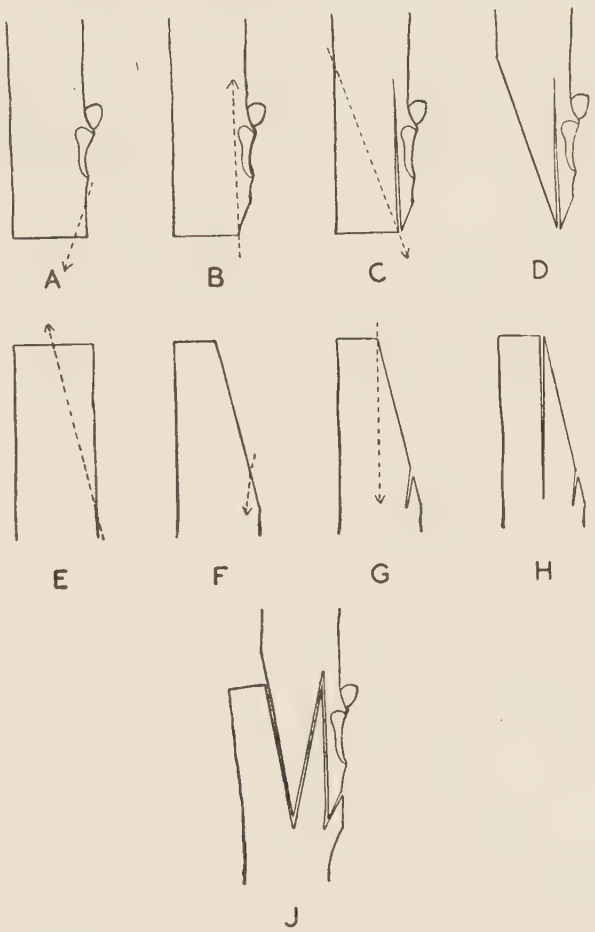


FIG. 1.

Walnut Grafting. Arrows show direction of cuts.

A - D. Cutting the scion. E - H. Cutting the stock. J. Scion on Stock.

buds are likely to succeed. It is a much cheaper method than grafting under glass, but at the moment the results are far less reliable.

A knife with two parallel blades is used. Such a knife can be made by fixing two small scalpels to a block. By means of this knife two parallel horizontal cuts about 1 inch apart are made on the stock, and a vertical cut connects them on one side. The bud sticks, the buds of which must be completely dormant, are collected from well-ripened growth made the previous year. Similar parallel cuts are made above and below the scion bud, and connecting vertical cuts on each side. The piece of bark with the bud is peeled away carefully, so as to give a rectangular patch with the bud in the centre. Special care must be taken to avoid damage to the base of the bud. The bark of the stock is then peeled back and the patch bud fitted. Finally the flap of stock bark is cut so that the edge coincides with the patch, and the whole tied firmly with soft crochet cotton or raffia.

This method may also be used to convert a seedling tree into a good named variety. Even if only a few buds take they usually grow vigorously and refurnish the tree within a few years.

## Cultivation.

**Soil and Site.** The Walnut will tolerate a wide range of soils so long as the drainage is good, and the soil not too acid. Lime should be applied before planting, unless there is plenty present in the soil.

The site should not be in a valley or frost hole because, although the dormant tree is quite hardy and can stand severe frost, the young growths and catkins are very easily killed by spring frosts.

**Planting.** November is the best time for planting, but it can be done during suitable weather at any time up to mid-March. It should be emphasized that Walnuts need very careful transplanting and care for the first year or two. The hole should be sufficiently large to take the roots comfortably, but any long roots may be shortened back. The tree should be planted very firmly, and staked and protected against damage by rabbits and grazing animals. It is very important that the roots should not be allowed to become dry during transplanting, as this is the chief cause of trees failing to become established.

The check at planting will be less if the tree is given a mulch during the following summer. If very dry weather occurs during the first year after planting, copious watering will greatly benefit the trees.

In America and on the Continent, Walnuts are often grown in plantations, but in this country the ground can generally be used more economically for other crops and they are mostly planted as avenues or specimen trees. If they are planted in groups they should be 30 to 60 feet apart, depending on the variety and soil.

Most Walnut trees need careful staking for the first 10 years of their lives.

**Training and Pruning.** With young trees the strongest shoot is trained on each year as the leader until the tree is about 8 feet high. It can then be left to form a head naturally. The trunk should be strengthened during the first few years by allowing the " feathers " to grow. These shoots should be pinched back as they grow in summer, so they do not become more than 9 inches long. After 3 or 4 years they may be removed altogether to leave a clean trunk of about 6 feet.

If one branch grows too strongly, it may be cut back in winter to restore the balance of the tree. Apart from this no pruning is required.

**Manuring.** Walnuts are often planted in grassland, in which case the ground for 3 or 4 feet around the tree should be cultivated during the first few years.

A mulch of farmyard manure or compost spread around the tree after the soil has warmed up in spring, and dug in during the autumn or winter, is the best form of manuring. It also helps the tree to withstand periods of drought during the summer. Artificial nitrogeneous manures should never be given in large amounts as they encourage soft growth which fails to ripen properly and dies back in winter.

## Growth and Crop.

**Time of leafing out.** Varieties differ in their vigour and habit of growth, but most make spreading round-topped trees. Walnuts are extremely susceptible to frost damage in the spring and for this reason time of leafing out is probably the most important consideration for trees in this country. Varieties that leaf out before the middle of April are unsuitable owing to the danger of the young shoots being frosted and the consequent failure of the trees to grow or crop. It is safer if they leaf out at the end of April or the beginning of May as they will then be more likely to escape frost injury.

**Pollination.** Another important factor is pollination. The Walnut is monoecious, i.e. it bears male and female flowers on the same tree. The male flowers (pollen catkins) occur on the one-year-old wood near the base of short shoots. The female flowers are borne in clusters at the end of short growths of the current season. The pollen is windborne and may be carried to trees over a quarter of a mile away, but fertilization appears to be surest when trees are pollinated with their own pollen.

Varieties fall into two groups—those in which the catkins commence to shed their pollen before the female nutlets are receptive (protandrous), and those in which the female flowers begin to be receptive before the catkins are ready to shed their pollen (protogynous). Trees in this latter group generally set the heavier crops as in their case the shedding of pollen and receptivity of the female flowers usually overlaps sufficiently, whereas this is less likely with protandrous varieties.

Grafted trees of most varieties bear female flowers when only a few years old, but do not bear catkins until later on. In order to get nuts from such trees quickly, it is necessary to have trees which are already bearing catkins close by, or to plant varieties nearby which bear catkins when young, or to hand pollinate with pollen brought from an older tree.

**Cropping.** Most of the varieties now recommended will bear some nuts at quite an early age, nd should carry crops of anything up to 10 lb. at 10 or 12 years. One or two varieties, e.g. Chaberte, arry fair crops at an even earlier age ; such varieties are usually those that produce both male and emale flowers in their early years.

Trees when young are prone to produce imperfect nuts. They may not be properly sealed, or he shell may have soft spots or even holes in it. In such cases the kernel is usually normal, but the uts will not keep for any length of time. This failure to form perfect shells is also associated with the eason, variety and vigour of the tree. As trees get older and less vigorous they tend to grow out of .. In summers when there is little sun, trees are apt to produce a rather high proportion of soft-helled nuts.

**arieties.**

For the reasons given above it will be realized that the choice of variety is all important. Brief escriptions of some of the better varieties for growing in this country are given below.

*Franquette.* Tree vigorous and spreading, leafing out very late, in the first or second week in May. rotandrous. Bears pollen catkins at a fairly early age. Nuts medium large, well sealed, of good uality.

*Mayette.* Tree vigorous and fairly spreading, leafing out at the same time as Franquette. rotandrous. Nuts medium large, well sealed, of good quality.

*Meylanaise.* Tree very similar to Franquette, leafing out at the same time or a day or two arlier. Slightly protandrous. Nuts medium size, well sealed, of good quality.

*Chaberte.* Tree vigorous and spreading, leafing out in the third or fourth week in April. Proto-ynous. Bears pollen catkins freely, even when young. Crops well and regularly, beginning at an arly age. May produce soft-shelled nuts in seasons without much sun. Nuts large.

*Excelsior of Taynton.* Tree very large and spreading, very vigorous in the nursery, leafing out n the third week in April. Protogynous. Bears pollen catkins regularly. Nuts large, with a thin hell, of good quality.

*Northdown Clawnut.* Tree of medium vigour, spreading, leafing out in the second or third week n April. Protandrous. Bears pollen catkins regularly. Nuts very large, thin shelled, of good quality nd very attractive appearance.

*Secrett.* Tree of medium vigour, with a compact head, leafing out in the third week in April. rotogynous. Nuts large, well sealed, of good quality and attractive appearance.

**Harvesting and Storing.**

Nuts, if grown for pickling, should be gathered green before the hard shells begin to form, i.e. before he end of July.

For dessert the nuts are left to ripen on the tree, and are either gathered as the outer husks are plitting, or left to drop and picked up off the ground every two or three days. Most varieties ripen towards the end of September.

The green outer husk should be removed as soon as the nuts are gathered, otherwise it becomes lack and difficult to remove, and leaves a discoloured shell beneath. The nuts should then be ipped in water (for a minute or two only, or they will tend to open), scrubbed with a soft scrubbing rush to remove all traces of fibre, and then dried in a cool current of air. When dry, well-sealed nuts an be treated with the following bleaching solution. This not only improves their appearance, ut also makes them more resistant to moulds.

Mix 3 lb. of chloride of lime to a creamy paste with a little water, in a 5-gallon container, add 2 gallons of water and stir well. Dissolve 1½ lb. of washing soda in water in another container, and pour into the chloride of lime solution. Add water to bring the total volume up to 5 gallons. Stir well and leave at least 24 hours to settle. The clear liquid can then be poured off and is ready for use.

The nuts are placed in this bleaching solution for 3 minutes, then taken out and dried in a single layer at room temperature.

Large earthenware jars or flower pots are suitable receptacles for storing Walnuts. The most effective storage medium is a mixture of equal parts, by weight, of salt and slightly damp coconut fibre. Alternate layers of this medium and cleaned nuts are placed in the jars, finishing with a good layer of the storage medium at the top. The jars must be placed where the rats and mice cannot get at them, as they will readily steal the nuts. Nuts stored in this way in a cellar or other cool place will remain plump and fresh for over 12 months.

## Diseases and Pests.

**Graft Disease** (*Chalaropsis thielavioides*). This disease is only of importance when Walnuts are being grafted. The fungus readily attacks the cut surfaces, covering them with a sooty powder, and preventing callus formation and union between stock and scion.

*Control.* A 1 per cent. solution of formaldehyde is toxic to the fungus, and complete control is obtained if the Propagating House and frames are sprayed with this solution, and stocks and scions painted with it just before the final cuts are made and the scion joined to the stock.

**Bacterial Blight** (*Pseudomonas juglandis*). This is the most important disease attacking Walnuts in this country. The bacteria produce small black spots on the leaves, often causing distortion of the leaflets. On the fruits, black, sunken lesions are produced with a characteristic water-soaked appearance (Fig. 2). Nutlets attacked when young soon drop off. Older nuts generally drop early, but even if they do mature are malformed and have black, soft regions in the shells. The kernels of such nuts are usually affected, and may be inedible. Early leafing varieties are liable to early attacks, which later leafing varieties often escape.

The bacteria overwinter in black lesions on the one-year-old shoots and also in the bud scales. They are spread in spring and summer by rain and mists.

*Control.* The stem lesions should be cut out in winter, to reduced the sources of infection.

A covering of Bordeaux mixture over the leaves and young nuts will reduce the chances of attack. As a routine treatment trees should be sprayed with Bordeaux mixture at 6 : 9 : 100 in mid-June and again in July. If, however, attacks have been bad in previous seasons, or the weather is very damp, it may be necessary to put on the first spray soon after leafing out and before flowering, and another immediately after flowering, and follow this with sprays at fortnightly intervals.

**Blotch** (*Gnomonia leptostyla* = *Marssonina juglandis*). This is very common in this country and is often confused with Bacterial Blight. The fungus forms small patches on the leaves, showing brown on the upper surface and grey underneath. Patches also appear on the green nuts (Fig. 3). The patches on the nuts are brown or black and slightly sunken, but may be distinguished from those caused by Bacterial Blight by their hard, dry edges and absence of the water-soaked appearance characteristic of the bacterial spots. They do not become as large as the bacterial lesions, and rarely affect the shell underneath.

The fungus overwinters on the fallen leaves, and spores from these leaves re-infect the young leaves and fruits in the following spring.

*Control.* This disease is rarely of much importance, but bad attacks early in the season may cause premature leaf fall, and may spoil nuts picked green for pickling.

The most effective method of control is to rake up and burn all the leaves as they fall in autumn.

**Damage by Rooks.** Rooks and other birds do much damage to nuts on the trees from the time the shells begin to harden until the nuts are gathered. The husk and shell are pierced, particularly near the apex of the nut, where the shell is usually thinnest, and the kernel eaten. Most of the damage is done early in the morning. The only method of control is to use some form of bird scarer, the best being an automatic gun. Similar damage is done by mice if the nuts are left on the ground after the husk has split.

Pickling nuts are not affected as they are picked before the stage at which the damage is done.

It is not advisable to plant Walnuts near a large rookery.

## Timber Trees.

Trees of *Juglans regia* make very good timber trees, and any of the varieties named above would, in addition, provide valuable crops of nuts while the timber was maturing. For good timber production the young trees should be trained up to have a clear trunk of at least 6 to 8 feet.

Trees of *Juglans nigra* (the Black Walnut) are also grown as timber trees. In this country the nuts are of little value, although in America they are used for confectionery purposes. They make tall-growing trees and give valuable timber. Either seedlings or grafted trees of named varieties can be grown.

## Summary.

Descriptions are given of the propagation and cultivation of Walnuts in England, with notes on some suitable varieties, and on the more important diseases attacking the Walnut.

Fig. 2.
Bacterial Blight

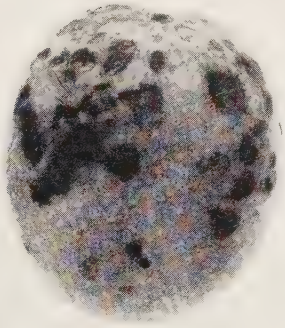

Fig. 3.
Blotch

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